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Thesis for the degree of
Doctor of Philosophy.

The Osteology and Myology
of
Amiurus catus (L) Gill.

by

J. Playfair McMurrich M.A.

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THE OSTEOLOGY OF *AMIURUS CATUS* (L.) GILL.

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Numerous statements regarding the osteology of the Siluroids have appeared from time to time in various works, such as the text-books of Stannius, Huxley, Claus, Wiedersheim, etc., and in many scattered papers, but, as far as I can discover, no complete study has been made of any one form. In the following pages I desire to recount the results of a detailed study of the various osteological elements of our common Canadian Siluroid, *Amiurus catus* (L.) Gill. The description of the various portions of the skeleton will be accompanied by some notes on the development of certain bones, as far as it has been possible to trace them, and a few remarks of a comparative nature.

I.—THE CRANIUM.

Viewed as a whole the cranium is extensively flattened, tapering from behind forwards in depth, so that a vertical longitudinal section would present a triangular aspect. Posteriorly are seen the five processes characteristic of the Teleostean skull, those of the pterotics, epiotics, and the median elongated supraoccipital spine. No well defined orbit is present, the postorbital process of the sphenotic being exceedingly small. A well marked antorbital process is, however, present, and in front of this at the anterior extremity of the skull two more lateral processes are formed by ossification of the lateral expansions of the ethmoid cartilage. On the upper surface of the skull are two median fontanelles; the anterior is the broadest, and is bounded by the frontals behind, and slightly by the mesethmoid in front; the posterior, which is long, tapering posteriorly, is bounded in front by the frontals, and posteriorly separates the supraoccipital into two halves, nearly as far back as the posterior surface of the skull. In accordance with the flattening of the skull, the canal for

the orbital muscles is exceedingly rudimentary, and very little cartilage remains in the skull, the anterior portion of the ethmoidal cartilage alone remaining unossified.

1. SUPRAOCCIPITAL.

This is the largest of all the occipital bones, but enters only very slightly into the boundary of the foramen magnum. Looking at it from above (Pl. II., Fig. 1, SO), it would appear to be divided into two portions, owing to the continuation backwards of the posterior fontanelle. Posteriorly, on either side of the fontanelle, it presents many minute foramina, belonging to the system of the mucous canals. Behind the posterior plane of the skull the bone is prolonged into a long spine, from the under surface of which a triangular ridge (Pl. II., Fig. 2, SO) projects downwards and bifurcating above the foramen magnum is continued downwards on the exoccipital. On the posterior surface, on either side of this ridge, is seen a foramen, which, from the inner surface, opens into a canal formed by the union of two others. Of these the superior and larger is occupied by the *ramus lateralis trigemini*, the lower, separated from former by a small spicule, by the ascending branch of the first spinal nerve. Below this latter opening is a third, leading into a canal which traverses the substance of the bone, running downwards and outwards, and containing in the living state the *canalis semicircularis posterior*. The supraoccipital articulates anteriorly with the *frontals*; laterally with *postfrontals*, *pterotics*, *epiotics* and *supraclavicle*; below with the *epiotics*, and *ex-occipitals*.

2. EXOCCIPITALS (Pl. II., Fig. 2, ExO).

Occupying the remainder of the boundary of the *foramen magnum* are the *exoccipitals*: each of which forms the three sides of a cube open above, in front, and on the inner side. A ledge of bone projects from the lower part of each bone inwards, meeting in the middle line, and forming the floor of the *foramen magnum*, and the roof of the *sinus impar*. The ridge of bone extending downwards from the lower surface of the supraoccipital spine is continued downwards on these bones, forming the lateral walls of the *foramen magnum*. On the outer surface are two foramina; the anterior small one gives passage to the *nervus glossopharyngeus*, and the posterior large one to the *N. vagus*. On the posterior surface is another

foramen, small, situated on a line with the inwardly projecting ledges, and giving passage to the first spinal nerve. The inner surface of the bone is smooth. The exoccipitals do not unite into a close articulation with neighbouring bones, but are merely placed in apposition, the outlines of the bones not being indented but perfectly smooth. They are in relation above with the *supraoccipital*, *epiotics*, and *pterotics*; in front with the *prootics*; and below with the *basioccipital.*

3. Basioccipital (Pl. II., Fig. 2, BO).

The Basioccipital is shut out by the exoccipitals from contributing to the formation of the *foramen magnum.* Its posterior face is deeply concave; below is a nutrient foramen; the upper surface forms the floor of the *sinus impar;* and the body of the bone is deeply hollowed for the reception of the *sacculus* of either side. It extends forwards, becoming smaller and thinner anteriorly, where it articulates with the posterior edge of the basisphenoid. Its articulations are as follows:—Above and at the side with the *exoccipitals*, and *prootics;* below with the *parasphenoid;* in front with the *basisphenoid;* behind with the body of the first vertebra; and laterally with the horizontal limb of the *supraclavicular.*

4. Epiotics (Pl. II., Fig. 1, EpO).

These bones, one on either side, form the postero-lateral angles of the skull. Each has an irregularly spherical triangular shape, affixed by the base, the apex forming the projecting angle. Internally the bone supports part of the posterior and longitudinal semicircular canals, the former passing in a deep groove on its posterior wall, the latter lying on the horizontal floor. The anterior upper edge of the bone is deeply channelled, the cavity communicating with a similar one in the substance of the pterotic. The articulations of the *epiotics* are with the *supraoccipital*, *exoccipital*, *pterotic*, and *supraclavicular.*

5. Pterotics (Pl. II., Figs. 1 and 2, PtO).

Form the postero-external angles of the skull. Each is an ossification around the arch of the horizontal semicircular canal. The posterior upper edge shows a wide opening extending some distance into the cavity of the bone, apparently separating the upper portion of the bone into two lamellæ. The groove mentioned above as occurring on the epiotic, and also one on the outer edge of the hori-

zontal portion of the supraoccipital, are parts of the same cavity. In a skull from which all accessory parts have been removed, it opens by a comparatively wide opening at the base of the ridge, which extends upwards upon the bone to unite with the similar ridge on the supraoccipital spine. This opening is almost closed in the natural condition by the supraclavicle, a small opening only being left. The cavity is apparently quite shut off from any communication with the brain-cavity, and contains only fatty tissue. On the upper surface of the pterotic, on the projecting posterior portion, are several foramina—the openings of a mucous canal, which passes forwards in an osseous canal, running along the outer edge of the bone. The smooth surface formed by pterotic, exoccipitals and epiotic lodges the utriculus. The pterotic articulates with the *supraoccipital* above; the *epiotics*, and *supraclavicular* behind; the *exoccipitals*, and *prootics* below; and in front with the *sphenotic*.

6. PROOTICS, (Pl. II. Fig. 2, *PrO.*)

Lie on each side immediately in front of the *exoccipitals*. Each is a somewhat quadrate bone, extending to the middle line below, where it articulates with the fellow of the opposite side, thus entering into the formation of the base as well as the walls of the skull. The middle portion of its inner surface is crossed by a ridge, notched outwardly, in which notch the anterior or sagittal semi-circular canal passes to the *recessus utriculi*. Near the posterior edge is another smaller ridge, round the outer extremity of which the same canal turns in passing forwards from the *utriculus*. Between these two ridges is a smooth hollow, with a very thin wall, which lodges the *recessus utriculi*. Below the prootics, where they meet in the middle line below and between them and the anterior portion of the basioccipital above, and the parasphenoid below, is a small cavity. This is the almost aborted rudiment of the canal for the orbital muscles, which is largely developed in many fishes, but absent or very rudimentary in *Silurus*, *Amiurus*, *Gadus*, *Lophius*, &c. The middle of the anterior edge of the prootic is notched variously in different individuals, sometimes possessing a single notch, at other times there being two more or less separated by an intervening osseous spicule. These notches are closed in front by the posterior edge of the alisphenoid, and through the foramina thus formed the fifth and seventh cranial nerves (*trigeminus* and

facialis) make their exit from the cranial cavity. The prootics articulate with the *exoccipitals* and *basioccipital* behind; above with the *pterotics* and *sphenotics*; internally with the fellow of the opposite side; anteriorly with the *alisphenoids* and *basisphenoid*; and below with the *parasphenoid*.

7. SPHENOTICS, (Pl. II. Figs. 1 & 2, *SpO.*)

Or postfrontals, present a flat surface on the roof of the skull, but send down a vertical longitudinal plate of considerable thickness, which is grooved deeply posteriorly, the arch of the anterior semi-circular canal being contained in the groove. On examining the bone from above, there may be seen below the surface a channel, a continuation of that already mentioned as traversing the pterotic, and containing a mucous canal. About the middle of its course on the sphenotic is an opening for a mucous pore, with which usually opens also a canal passing from the cranial cavity and giving exit to a dorsal branch of the *trigeminus*, though it occasionally opens separately. From the same point another channel in the bone passes inwards, opening by a pore on the line of articulation between the *postfrontal* and *frontal*. This also contains a mucous canal. On the under surface, near the external edge, is a longitudinal groove continued from pterotic which is the articular surface for the hyomand. The vertical portion of the bone forms the superior boundary of the foramen for the *trigeminus* and *facialis*, and is not continued forwards to the anterior extremity of the bone, which is there formed solely of a horizontal plate. The sphenotic articulates with the *supraoccipital* and *pterotic* posteriorly; below with the *prootic;* in front with the *alisphenoid;* and above and internally with the *frontal*.

8. PARASPHENOID, (Pl. II. Fig. 2, *PaS.*)

This bone, lying at the base of the skull, extends from the basioccipital, which it slightly overlaps, to the vomer anteriorly, by which it is overlapped. About the junction of the anterior two-thirds with the posterior third it expands somewhat, extending upwards to articulate with prootic. Behind it forms the floor of the small rudiment of the canal for the orbital muscles, and its expanded portion is firmly anchylosed with the superjacent bone, the basisphenoid. The

parasphenoid lies below the *basioccipital* behind, and also passing forwards, the *prootic*, *basisphenoid*, *orbitosphenoid* and *ectethmoid*.

9. Basisphenoid.

Does not appear as a distinct bone in the skull of *Amiurus* but is anchylosed with the subjacent parasphenoid, the line of demarcation between the two being more or less distinct however. It is a flattened impair bone, presenting no especial features for examination. It forms the lower boundary of the foramen for *trigeminus* and *facialis* behind, and partly of the foramen for *opticus* in front, and articulates behind with the *prootic ;* externally with the *alisphenoid ;* in front with the *orbitosphenoid ;* and below with the *parasphenoid.*

10. Alisphenoid, (Pl. II. Fig. 2, *AS.*)

A rather small bone, lying on either side between the foramina, of which it forms the anterior and posterior boundaries, respectively. These foramina are that for the *trigeminus* and *facial* behind, and that for the *opticus* in front. The bone is very roughened and ridged on its external face for the attachment of muscles, and above this roughened portion is a hollow in which lies the anterior portion of the hyomandibular. The inner surface is smooth. From the posterior edge a spicule of bone passes backwards in those individuals, in which the foramen for passage of the 5th and 7th nerves is divided completely, which spicule unites with a similar one from the prootic. Immediately in front of posterior edge is a small foramen for exit of the *ciliary* trunk of the 5th nerve. On the inner side, immediately above the inferior process, which articulates with the basisphenoid, are two foramina, one above the other. The inferior of these is the larger, and opens into a canal, pursuing a course more or less oblique in different individuals to the exterior. It gives passage to the deep branch of *R. ophthalmicus trigemini.* The smaller one lies at the extremity of a longitudinal groove, and opens into the interior of the bone like other similar foramina which perhaps, have a nutritive function. Each alisphenoid articulates above with the *sphenotic* and *frontal ;* behind with the *prootic ;* below with the *basisphenoid;* and in front with the *orbitosphenoid.*

11. Frontals, (Pl. II. Figs 1 & 2, *Fr.*)

Are flat plate-like bones, with a small ridge projecting downwards from the middle of the under surface. They are separated from each

other along nearly the whole of their length, entering into the formation of the anterior and posterior fontanelles, their articulation being only at a small surface about their middle point. The mucous canals, which run in the pterotics and sphenotics continue their forward course in these bones, which present many foramina or mucous pores. On the upper surface one of these is especially noticeable, situated on a level with the anterior extremity of the articular surface on each side. Below, on the inner side of the vertical ridge, is a small foramen which is for the exit of a small dorsal branch of the *trigeminus*. On the outer side of the ridge are a varying number of foramina, varying even on opposite sides of the same skull both as to size and number. In front of these a groove runs forward to a foramen in the very front of the bone, opening into the nasal capsule and giving passage to the *opthalmic* branch of the fifth which exits from the skull through the alisphenoid. The frontals articulate internally with the fellow of the opposite side ; below with the *alisphenoids*, *orbitosphenoids* and *ectethmoids ;* behind with the *sphenotics* and *supraoccipitals*.

12. ORBITOSPHENOID, (Pl. II. Fig. 2, *Os.*)

A single bone forming the base and walls of the skull, the cavity of which is contracted in this region, expanding both in front and behind. It forms a passage or canal in which lie the olfactory nerves. Immediately above the horizontal portion the bone is notched deeply anteriorly and posteriorly. These notches are made foramina by the articulating bones. Through the anterior one a vein passes, through the posterior, the *optic* nerve. The *orbitosphenoid* articulates in front with the *ectethmoids* and *mesethmoids ;* above with the *frontals ;* behind with the *alisphenoids* and *basisphenoid ;* and below with the *parasphenoid*.

13. MESETHMOID, (Pl. II. Figs. 1 & 2, *MEth.)*

Forms the anterior boundary of the skull, and enters into the formation of the floor and the roof of the anterior portion which contains the olfactory nerves. It is the median ossification of the ethmoid cartilage of the young fish, and is one of the two bones in which the ossification of the cartilage is not completed in the adult, the inner surface of the bone being lined with it. In front it is notched, and spreads out into two horn-like processes which articulate below with

the premaxillæ. Its posterior articular surfaces, both above and below, are very much indented, split up, in fact, into a number of very long osseous spicules, as in the parasphenoid and vomer, which fit in between corresponding spicules in the bones with which it articulates. Its articulations are :—behind with the *orbitosphenoid*, *frontals* and *parasphenoid ;* below with the *parasphenoid*, *vomer* and *premaxillæ* ; laterally with the *ectethmoids*.

14. ECTETHMOIDS, (Pl. II., Figs. 1 & 2, *EEth* ; Fig. 2, *Pfr.*)

Are the lateral ossifications of the ethmoidal cartilage. They are very deeply grooved on the inner surface for the *olfactory* nerves, opening anteriorly by a large foramen, through which the nerves pass to the olfactory organ. Laterally the bone is produced into a strong slightly curved process, the *antorbital process*, and below this is a roughened surface for articulation with the posterior extremity of the palatine. The lower and posterior surface of the antorbital process presents one or two foramina through one of which a branch from the deep branch of *R. ophthalmicus trigemini* passes. The upper surface of the bone is irregular, and presents many foramina connected with the mucous canal system. The ectethmoids articulate with the *mesethmoid* interiorly ; the *frontals* and *orbitosphenoids* behind ; the *vomer* below, and the *palatine* externally. Their upper surfaces also come into relation with two membrane bones, the *nasal* and the *adnasal*, on each side, and the extremity of the antorbital process is in relation to the anterior ossicle of the *infraorbital chain*.

15. VOMER, (Pl. II., Fig. 2, *Vo.*)

Is a nail-shaped bone, *i.e.*, very much expanded in front, and abruptly narrowed and tapering toward the posterior extremity. It lies below the *mesethmoid* and anterior portion of the *parasphenoid*, with which it interdigitates.

Certain membrane bones, developed in connection with the mucous canal system, may also be described as belonging to the cranium ; these are the *infra-orbitals*, the *nasals*, and the *adnasals*.

16. INFRA-ORBITALS.

Extending from the frontals downwards behind the orbit, and below it bending and running forwards to the ectethmoid, is a chain of bones lying in the dense fascia which covers the *adductor mandibulæ* muscle. The first or superior is an almost square bone, the second

long and slightly curved, lying directly behind the eye. It is followed by the third, almost straight and shorter than the second ; the fourth, fifth and sixth are straight rod-like bones, longer than the first or third, the sixth being the shortest of the three. All are traversed by a channel in which lies a mucous canal, more or fewer possessing an opening by which the canal communicates with the exterior.

17. ADNASAL. Pl. II., Fig. 1. *An.*)

A small bone on either side, lying at the base of maxillary tentacle in the fascia covering the nasal region. It is really a continuation forwards of the infraorbital chain, containing the same mucous canal, which opens by a pore on its surface. The bone is slightly triangular, with curved edges, the apex being directed forwards.

18. NASALS, (Pl. II., Fig. 1, *Na.*)

Are small bones in *Amiurus*, lying on either side between the *adnasal* and the *mesethmoid*. They are oblong in shape, and are traversed by a channel for a mucous canal which opens by a pore on the outer edge of the bone.

On comparison with other Teleostean crania, the almost entire absence of cartilage is a very noticeable feature. Ossification has progressed so far in every part that it has replaced the original cartilage entirely, except in the mes- and ectethmoid. Since the cartilaginous stage precedes in the ontogeny the osseous stage, one must conclude that a form whose skull is completely ossified is phylogenetically older than one whose skull contains a considerable amount of cartilage, and, therefore, *Amiurus* and the *Siluroids* in general form a highly specialized group, which indeed other points in their anatomy also show. The absence of a canal for the orbital muscles would also appear to characterize only highly specialized types. It is found in forms in which much of the original cartilage persists, but in this form only a rudiment of it is present, indicating its presence in the ancestral forms of the *Siluroids*. Vrolik[1] mentions a fact in connection with the absence of the canal which receives confirmation in *Amiurus*, namely, that when such is the case, the petrosum (*prootic*) is not pierced by the facial and trigeminus (*Gadus*, *Silurus* and *Lophius*).

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[1] *Vrolik.*—Studien uber die Verknocherung u. d. Knochen des Schadels d. *Teleostei*. Niederland. Arch. f. Zool.—Bd. I., 1873.

As regards the various bones of the skull, they differ in no very essential points from those of *Silurus glanis*, which have been described in general terms and for comparative purposes only by Vrolik. All the bones usually found in Teleostean crania are present with the exceptions of the opisthotic, intercalare, and parietals. The principal features are the presence of a well-ossified and large mesethmoid ; the orbitosphenoid forming three sides of a canal for the olfactorius, thereby separating widely the eyes and acting as an interorbital septum ; the meeting of the prootics at the base of the skull ; and the absence of teeth in the vomer, a point of some importance, since certain closely related forms are provided with vomerine teeth.

Certain points in the development of the cranial bones merit a detailed description. In a young *Amiurus*, about 20 mm. in length, it was to be noticed that wherever a mucous canal appeared in transverse section a ring of bone surrounded and protected it, (Pl. II., Fig. 8, MC), so that each of these canals in the cranium was surrounded by an osseous tube. The bone was apparently deposited in membrane, and was evidently formed solely for the protection of the mucous canal. In certain cases a bone, usually perforated for the emission of a branch from the canal to a pore, became formed by a lateral extension of this osseous tube into the adjacent connective tissue. Instances of such bones are the infraorbital chain, the adnasals and nasals. The adnasals in reality, then, as was stated above, belong to the same group as the bones of the infraorbital chain, and may be described as the anterior ossicle of that chain, since it is formed in the same manner, and is traversed by the same canal. Sagemehl[1] proposes to name it the antorbital, but, since its function is not only to protect the enclosed mucous canal but also to protect the nasal region to which it stands in the same relation as does the nasal, I prefer the name employed.

In the majority of cases, however, the osseous tube does not remain distinct but fuses with the subjacent bone, whether formed in membrane or perichondrally. In the case of the frontals, for instance, the mucous canal bone unites with the underlying bone formed in membrane, and in the sphenotic and pterotic (Fig. 8) a similar union occurs with the perichondral bone with which the ossification of the

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[1] *Sagemehl.*—Beitrage zur vergl. Anat. der Fische. Das Cranium von *Amia Calva. L.*, Morph. Jahrb. Bd. IX , 2nd Heft. 1883.

cartilage of those regions commences. As regards the former it must be noted that there is apparently a portion (the thin ledge-like portion overlapping the anterior portion of hyomandibular) which is formed entirely by membrane. These two bones, then, are partly formed perichondrally, and partly from bone originating in membrane, and, accordingly, objections to the pterotic being considered equivalent to the other otic bones on account of its possessing a mucous canal, are groundless, since the pterotic and sphenotic are in reality cartilage bones for the protection of semi-circular canals, the union of the membrane bone being secondary, and probably for the purpose of increasing the strength of the protective tube of the mucous canal. Schmid-Monnard[1] has recently pointed out the part played by the mucous canal in the formation of the pterotic, but does not seem to have noticed it in the case of the sphenotic.

Sagemehl[2] also points out that the sphenotic postfrontal) and also the prefrontal (ectethmoid) in *Amia* possess a membranous element, but does not recognize in the sphenotic that the membrane bone really belongs to the mucous canal. As regards the ectethmoid in *Amiurus*, it is truly perichondral, for the mucous canal which lies above it does not unite with it, but is separated from it by connective tissue.

As regards the other bones, the prootics, epiotics, alisphenoids, and basisphenoid, are entirely perichondral in their formation; the supraoccipital is partly perichondral and partly formed from a superficial plate of membrane bone, which unites with the subjacent perichondral; the orbitosphenoid is mainly perichondral, but the cartilaginous orbitosphenoids do not meet in the middle line, but leave a space at the base of the skull bridged over by membrane continuous with the perichondrium, from which the median basal portion of the bone is developed. The ex-occipital, too, is mainly perichondral, the two ledges which roof in the sinus impar being, however, membranous in their origin.

The basioccipital, however, presents several points for consideration in its development. In the young stage above mentioned, at the median line at the base of the skull is the notochord, surrounded with some osseous tissue apparently developed from its sheath, as in the vertebræ. The lower angles of this ossification are continuous

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[1] *Schmid-Monnard.*—Die Histogenese des Knochens der Teleostier Zeit. f. wiss Zool Bd XXXIX., 1883.

[2] *Loc. cit.*

with a thin layer of bone extending across and becoming continuous with the outer perichondral layer of the exoccipital. This thin layer forms the floor of the cavity for the sacculus, and contains no cartilage, so that the basioccipital at this stage is destitute of cartilage, and is composed of membrane bone in this (anterior) region. More posteriorly, however, behind the exit of the vagus and behind the cavity for the sacculus, the cartilage, continuous with that of the exoccipital, comes down towards the middle line as far as the chorda, which is still surrounded by bone. In an older stage (about 38 mm. in length) the cartilage present around the chorda and on the floor of the cavity for the sacculus is very noticeable. Opposite the exit of the glossopharyngeal, where no cartilage was to be seen in the younger stage, a large plate of it is present at floor of the sacculus-fossa, bearing upon its upper (inner) surface a mass of trabecular bone representing the ossification around the notochord in the younger stage. So opposite the foramen for the vagus (where no cartilage is present in the younger stage) the chorda has much diminished in size, and cartilage is to be seen at its sides below, separated from it by a layer of bone. Still more posteriorly the cartilage has the same relations as in the younger stage.

It is thus seen that the older stage presents cartilage where in the younger stage only bone is present, apparently reversing the fact that the older the form the less the amount of cartilage present. How is this to be explained? In the young stage the sacculus occupies the place of the cartilage, being so large in comparison to the size of the skull that there is room only for a thin layer of bone at the floor of the fossa, and a thin investment round the chorda. Later, however, the cranium grows more rapidly than the auditory apparatus, and then the cartilage always present posteriorly grows forward, and, by the ossification of its perichondrium, contributes largely to the formation of the basioccipital.

The vomer and parasphenoid are formed in membrane and show no signs of teeth.

Objections have been made by certain German authors to the application of the terms proötic, epiotic, etc., to the bones developed in the cartilaginous ear-capsule. Vrolik[1] bases his objection to the terms on the fact that other bones, for instance, the supra-, ex-

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[1] *Vrolik.*—Studien über die Verknocherung u. d. Knochen des Schadels der Teleostei. Niederlandisches Archiv fur Zoologie, Bd. I. 1873

and basioccipital, also enter into the protection of the auditory apparatus, and that in *Salmo* (the only instance apparently observed by him) the epiotic does not contain the exterior semicircular canal. The cartilage in which the occipital bones develop did not originally form part of the auditory case, the passage of the semicircular canal through the exoccipital and supraoccipital being secondary, as the hollowing out of the basioccipital for the sacculus certainly is, so that the names applied to these parts more truly indicate their origin. Parker's paper on the skull of the salmon,[1] published later in the same year, states that, contrary to Vrolik's opinion, the epiotic *does* arise in connection with a semicircular canal, and shows also that a similar relation occurs in the pterotic, sphenotic, and opisthotic.

In the *Selachii* the auditory capsule is at first quite distinct from the rest of the skull, with which it eventually fuses, and throughout life remains without connection with the cranial cavity except by the foramen for the auditory nerve. It lies at the sides of the skull, but does not extend back to the occipital region. In young Teleosts the cartilaginous capsule does not extend back as far as the occipital region, lying still at the sides. Now all bones formed in this cartilaginous capsule are certainly entitled to be referred to the "otica" group. The anterior portion of this capsule is ossified as the proötic (petrosum), a tract of osteoblasts outside the ampulla of the anterior semicircular canal gives origin to the sphenotic (postfrontal), the pterotic (squamosal) arises over the ampulla and arch of the external canal, the epiotic (occipital externum) over the arch of the posterior canal, and the opisthotic (intercalare) over the ampulla of the same canal. All these bones lie in the region occupied by the cartilaginous auditory capsule, all are mainly what may be called cartilage bones,[2] and all hold a more or less definite relation to the included auditory apparatus.

The terms proötic, sphenotic, pterotic, epiotic and opisthotic, applied respectively to the bones known to German authors as the petrosum, postfrontal, squamosal, occipitale externum, and intercalare, are preferable, as indicating the true relations of these ossifications.

Sagemehl in his paper on *Amia*[3] makes many ingenious and

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[1] *W. K. Parker.*—The structure and development of the skull in the Salmon. Phil. Trans., 1873.

[2] Gegenbaur's objections to the pterotic (Ub. das Kopfskelet von Alepocephalus rostratus (Risso). Morph. Jahrb, Bd. IV., suppl., 1878,) have been shown above to be groundless.

[3] *Ante cit.*

valuable suggestions. His paper coming to hand after the previous descriptive portion had been written, explains the homology of the cavity described as occurring in the upper surfaces of the pterotic, supraoccipital, and epiotic. He shows that a similar cavity, which he terms the *temporal cavity*, occurs in *Amia* between the bones and the primordial cartilage, is widely open behind, and contains a portion of the lateral musculature. In all probability the cavity in *Amiurus* is a rudiment of this temporal cavity of *Amia*, the original contents of which have vanished, their place being taken by fat and blood-vessels.

The same author suggests that the occipital segment of the Teleosts has fused with it a certain number of vertebræ. He bases his assertions on the presence of such vertebræ, partially fused, in *Amia*, *Polypterus*, *Protopterus* and *Lepidosteus*. If such be the case, there is no trace of such a coalescence in *Amiurus*. A nerve certainly does pass out from the exoccipital behind the vagus, but in all its relations it is a spinal nerve, passing through the arch of the preceding vertebra, as do the succeeding nerves. The occipital segment is certainly composed of many segments, one corresponding to each branchial branch of the vagus and to the glossopharyngeal, but beyond these there is no indication of any further segments in the basioccipital of *Amiurus*.

II.—PALATO-QUADRATE AND MANDIBULAR APPARATUS.

Under this head will be included a description of the maxillary and palatine apparatus, as well as of the chain of bones constituting the first postoral arcade, or, according to views expressed elsewhere,[1] the third cranial arcade, the trabeculæ cranii being considered as representing the first arch, and the palatine as the second.

1. THE PREMAXILLÆ, (Pl. II., Fig. 1, *Pmx.*)

Each is a small, somewhat arched bone, supporting five or six rows of teeth. They meet in the middle line, but are not united by suture. The upper surface of each bone rests on the under surface of the *mesethmoid*, and at the outer extremity each articulates with the *maxilla*.

2. THE MAXILLÆ, (Pl. II., Fig. 1, *Mx.*)

Depart very widely from the typical form. They are very much elongated rods, projecting at right angles to the sides of the skull,

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[1] On the Osteology and Development of Syngnathus Peckianus (Storer). Quart. Journ. Micr. Sci., N. S., Vol. XXIII, 1883.

but are capable of considerable movement, so that they may lie almost parallel to the longitudinal axis. At the base the bone forms a complete sheath for the cartilage which supports the maxillary tentacle, but this sheath is complete only for a short distance, the cartilage lying in a groove in the posterior (inner) surface of the bone. At the base are two processes, a smaller posterior dorsal and a larger anterior ventral. The latter has a fascia firmly attached to it in such a way that, when the anterior extremity of the palatine is pushed forward, it draws the same fascia, and by the tension thus produced the maxilla is abducted or pushed away from the sides of the skull. The bones possess no teeth. They have in relation to them the *premaxillæ* in front and below; the *palatines* behind; and the *adnasals* on the inner side.

3. THE PALATINE, (Pl. II., Fig. 1, *Pa.*)

Each palatine is a short, rod-shaped bone, extending antero-posteriorly, parallel with the long axis of the skull. The anterior extremity abuts upon the maxilla, and the posterior lies in front and outside of No. 4, and below the antorbital process of the *ectethmoid.*

4. (Pl. II., Figs. 1 & 4).

This is a small almost round scale-like bone, lying behind and within the posterior extremity of the palatine. It is developed in the fascia of the anterior fibres of the *adductor arcûs palatini* muscle, and cannot be referred to the pterygoid series of bones. In a specimen of the very closely related *Amiurus nigricans,* (LeS) Gill, it was quite absent.

5. METAPTERYGOID, (Pl. II., Fig. 1, *Mpt.*)

Is an almost square bone, lying directly behind No. 4. It is flattened, and its upper posterior border is somewhat concave, aiding in the formation of the notch for the passage of the trigeminus to the superficial muscles. The anterior superior angle is attached by ligament to the *orbitosphenoids.* The bone articulates in front with No. 4; behind with the *hyomandibular,* and below with the *quadrate.*

6. THE QUADRATE, (Pl. II., Fig. 1, *Qu.*)

Furnishes the articular surface for the mandible. It is triangular in shape, thicker behind and below, the upper portion being squamose. In a deep fossa, on the upper and posterior portion of the

bone, lies the cartilaginous *symplectic*, in a perfectly dried skull, the fossa being empty and an interspace occurring between the quadrate and the hyomandibular. The posterior border of the quadrate is contained in a groove on the *preoperculum*; behind and above it articulates with the *hyomandibular*; and above and in front with the *metapterygoid*.

7. THE MANDIBLE, (Pl. II., Fig. 1, *Mn.*)

Consists of two portions, one on either side, united in the median line in front by ligament. Each portion again consists of four parts. These are as follows:—

(*a*) The *dentary*, constituting the anterior two-thirds of the bone and bearing numerous teeth. It is broader in front than behind, the teeth being arranged correspondingly, there being 5-6 rows anteriorly, tapering off to two rows posteriorly. The bone increases in height posteriorly, and is grooved on the inner surface for the reception of Meckel's cartilage and the articulare. The under surface presents six pores, openings for branches of the mucous canal which runs in this portion of the bone.

(*b*) The *articulare* forming the posterior high portion of the bone, and presenting the articular surface for the quadrate. It encloses Meckel's cartilage posteriorly.

(*c*) *Meckel's cartilage*, the remains of the primordial cartilaginous mandible. It consists of a rod of cartilage lying on the inner surfaces of the dentary and articulare, its posterior portion being included within the latter.

(*d*) The *angulare*, fused completely with the articulare, being merely indicated as a small triangular nodule below the articular surface.

The great size of the intermaxillaries and the limitation of the teeth to them, as far as concerns the upper jaw, are points worthy of notice. This is, of course, due to the specialization of the maxillæ for another purpose; with the decrease in size of the latter was an increase of the former. The intermaxillæ belong to that class of bones which are formed by the fusion of cement-plates of teeth. At first they are represented by a thin lamella of bone-bearing teeth, but by means of osteoblasts the ossification extends into the superjacent tissue in the form of trabeculæ which are, in their histological details, similar to the cement plates.

The maxillæ are specialized for the support of the long maxillary tentacles. Instead of developing parallel to the axis of the skull, they extend outwards at right angles to it, their antero-posterior extent being very much diminished. They have, in fact, lost all the usual relations to the gape. That they do not possess teeth is not remarkable, since even in *Esox* they are toothless, though probably their origin was similar to that of the intermaxillæ, *i.e.*, the union of cement plates. The fact of their being moved by a special muscle lying below the *adductor mandibulæ*, instead of by the upper layer of that muscle, and also their relation to a nerve arising from the trigeminus before its division into the superior and inferior branches, which seemed to indicate for them an angular nature, gave rise to a passing idea that they might not really be homologous with the maxillæ of other Teleosts, and I was inclined for a time to compare them to the supramaxillaries described by Gegenbaur as occurring in *Alepocephalus* and *Clupea*[1]. These peculiarities, however, do not properly belong to the bones but to the tentacle, and, since the relations of the bones are the same as those of the maxillæ of other Teleosts, and their mode of development similar, there seem to be no reasons for departing from the usual idea that they are homologous with the maxillæ of other osseous fishes.

The palatine bears no teeth. The first trace of bone is formed by the perichondral investment of the ethmo-palatine cartilage, this osseous layer having similar histological characters to the cement plates, there being evidently a close relation between these two forms of bone.

The true pterygoids are all so-called cartilage bones, and therefore the bone described as No. 4 cannot belong to the series. Its true relations have already been indicated. The presence of only one pterygoid is, however, a peculiar feature. In the youngest stage which I was able to study, ossification had just commenced, and by means of sections[2] it was seen that the anterior portion of the metapterygoid contained no cartilage, there being thus, apparently, an interval between the anterior extremity of the pterygo-quadrate

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[1] *Loc. cit.*

[2] I must testify to the good results obtained by the use of a saturated watery solution of Bismarck Brown. Not only are cartilage and bone admirably differentiated, but also muscle, nerve, glandular tissue, etc.

and the posterior extremity of the ethmo-palatine cartilages. Whether this is really so my specimens do not allow of absolute certainty, but make it a strong probability. Somewhat further back the cartilage is seen and may be traced unbroken back to the quadrate. The metapterygoid of *Amiurus* combines to a certain extent the relations of the ectopterygoid and entopterygoid, as well as that of the metapterygoid of other Teleosts, but, since it is in direct relation to the quadrate, and performs the usual function of a buttress to the hyomandibular, I have preferred the last named term for it.

The development of the dentary suggests some important thoughts. In a 20 mm. stage, (Fig. 9) Meckel's cartilage *Mck*) is present in its entirety. On its upper surface is a layer of tooth-bearing bone, in which the individual cement plates (*cp*) are still to a large extent recognizable. At the sides and below is a layer of perichondral bone (*pc*), the cement plate bone passing into it without any line of demarcation. In fact both varieties are identical, not only in their histological features, but also in their origin. Below the cartilage is a mucous canal (*MC*) enclosed in its osseous tube, which is united with the perichondral bone of the lower surface. In a 38 mm. stage the cartilage has almost disappeared, its place being occupied by trabeculæ of bone, osteoblasts lying in the interspaces. The mucous bone has become quite united with these trabeculæ, and it is impossible to distinguish it. We have then in the dentary portion of the mandible what may be termed three different varieties of bone—cement-bone, perichondral-bone (with which may be included the trabeculæ), and mucous-canal bone. All three, however, pass into each other, and are indistinguishable in structure and origin. The old division into primary and secondary ossification should be done away with since both varieties are in reality similar.

III.—THE HYOMANDIBULAR, HYOID, AND OPERCULAR APPARATUS.

The bones constituting these parts belong to a single arch, the second post-oral, and are in relation to the seventh nerve.

1. The Hyomandibular, (Pl. II., Fig. 1, *Hmd.*)

Is a large almost quadrate bone, forming the upper part of the arch. It articulates above by a somewhat arched surface with the *sphenotic* and *pterotic*, and from the anterior angle of this surface a

process passes forward and upward to touch upon the *alisphenoid.* Upon the inner surface of the bone, not far from the base of this process, is a foramen leading into a canal which traverses the hyomandibular from above downwards and backwards, opening on its posterior surface a little above the posterior inferior angle. This canal contains the *R. hyoideo-mandibularis facialis.* On the outer surface is a flattened ridge overlying this canal, immediately behind which is the articular knob for the operculum, and extending forward at right angle to it is a ridge for the attachment of muscles. The hyomandibular articulates above with the *pterotic*, *sphenotic*, and *alisphenoid* ; in front with the *metapterygoid*, and slightly with the *quadrate* ; below with the *symplectic* cartilage and the *preoperculum* ; and behind with the *operculum.*

2. The Symplectic

Element does not appear to ossify. It is represented by a cartilage contained partly within the hyomandibular and partly within the quadrate, and filling up the space between these two bones.

3. The Hyoid

May be described as consisting of five portions, as follows :—

(*a*) The *interhyal* is represented by a small knob at the extremity of the arch which is connected by ligament to the inter- and preoperculum, the hyoid thus being fixed at its upper extremities without articulation with the symplectic.

(*b*) The *epihyal* is the upper triangular portion of the arch, separated from the succeeding portion by a deep notch above and below, and by a usually well marked articulation.

(*c*) The *ceratohyal* is the longest portion of the arch ; broad and flat above, it becomes contracted towards its anterior extremity and again expands for articulation with the hypohyals. Both the ceratohyal and epihyal bear branchiostegal rays on their lower borders.

(*d*) The *hypohyal* is united with its fellow of the opposite side by ligament. The bone so denominated in *Amiurus* is not simple, but has usually connected with it one or two accessory nodular bones, the number frequently varying on opposite sides in the same individual.

(*e*) The *urohyal* is an impair bone extending back from the junction of the hypohyals. Anteriorly it is partly divided into two rounded portions, from the extremities of each of which a ligament passes forward uniting it to the hypohyal. Behind is a thin flattened

plate, bearing on its upper surface a high longitudinal keel which bifurcates anteriorly, each division continuing its way upon the anterior round portion, diminishing as it passes forward. Upon the upper surface of the flattened portion, and separated from each other by the median keel, are the two *hyo-clavicular* muscles.

4. THE BRANCHIOSTEGAL RAYS,

According to Jordan[1], the typical number of branchiostegal rays for *Amiurus* is nine, varying, however, from eight to eleven. The variation seems to occur even individuals, there being, for instance, sometimes nine on one side and eight on the other. In *Amiurus catus* the usual number was eight. They arise from the posterior (inferior) borders of the epihyals and ceratohyals, which possess notches for their articulation. The inner ones are short and rounded, but the outer (superior) ones are more or less flattened, the last two being quite flat and applied to the under surface of the operculum. In fact I would prefer to state the number of the rays at seven, considering the upper one as the suboperculum.

5. THE PREOPERCULUM (Pl. II., Fig. I, *PrOp.*)

Is more or less firmly united with the hyomandibular and quadrate. It is broader at the lower part than above, and is grooved on its anterior border for the reception of the lower part of the hyomandibular, the symplectic, and the quadrate. It is a continuation of the longitudinal flattened ridge of the hyomandibular and contains a mucous-canal, foramina upon its surface being for the exit of branches to the pores. Behind and below it rests upon the *operculum* and *interoperculum.*

6. THE OPERCULUM (Pl. II., Fig. 1, *Op.*)

Is a triangular scale-like bone, articulating with the knob on the hyomandibular. Its apex is in relation to the *interoperculum.*

7. THE INTEROPERCULUM (Pl. II., Fig. 1, *IOp.*)

Is a short, stout bone, lying between the apex of the operculum and the posterior extremity of the mandible, with which it is united

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[1] *Jordan.*—Manual of N. Amer. Vertebrates, Chicago, 1876.

by ligament. It is also firmly united by ligament to the upper portion of the *epihyal.*

8. THE SUBOPERCULUM.

As above indicated, is seen in the uppermost branchiostegal ray, which occupies exactly the position of the suboperculum in other Teleosts.

The large anterior extension of the hyomandibular, whereby the metapterygoid is thrust forwards, is a characteristic feature. On examining a young stage it is seen that this extension is not an ossification originally represented by cartilage, but is a growth forwards of the perichondral bone of the hyomandibular cartilage into the membrane lying in front. This appears to have been originally due to the relations of the *R. hyoideo-mandibularis N. facialis*, the growth being later on carried still more forwards for the attachment of muscles. This has resulted in the hyomandibular usurping the position of the metapterygoid. and its functions as regards the origin of the *musc. adductor mandibulæ*, the longitudinal ridge usually being in the metapterygoid.

The relations and origin of the opercular bones at one time aroused much discussion ; some light is apparently thrown upon these points by *Amiurus*. but, before enunciating any theory, it may be well to state briefly the ideas of earlier authors.

The earlier writers, such as Geoffroy Saint-Hilaire and Spix, were inclined to consider the opercular bones as comparable to the auditory ossicles of the mammalia. Thus the former terms the preoperculum, the 'tympanal,' the operculum, the 'stapéal,' the suboperculum, the 'malléal,' and the interoperculum, the 'inceal ;' while, according to Spix, the same bones are respectively, leaving out the suboperculum, the 'marteau,' the 'enclume,' and the 'étrier.' Cuvier[1] denies these relationships, saying "—— plus on examinera les pièces operculaires, plus on se convaincra que ni leurs connexions entre elles et avec les autres os, ni les muscles qui les mettent en mouvement, ne présentent le moindre rapport avec les osselets dont il s'agit." Neither deBlainville or Agassiz believed in the auditory theory, the former believing the opercular bones to belong to the

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[1] *Cuvier et Valenciennes.*—Hist. nat. des Poissons. Paris, 1828.

subcutaneous system, and the latter to the system of the branchiostegal rays. Hollard[1] sums up his observations thus, "En d'autres termes et pour nous résumer, il résulte pour nous de cette étude que le battant operculaire des Poissons se divise, quant à sa signification anatomique, entre le squelette normal et un squelette supplémentaire et cutané ; que l'interopercule appartient au premier, comme naissant et se développant dans le premier arc viscéral ; qu'il occupe la même place que l'enclume des mammifères ; qu'enfin l'opercule et le sous-opercule, loin de lui faire suite, loin de pouvoir être assimilés aux autres osselets de l'ouïe ou à vrais appendices, sortent des limites du névro-squelette, non, comme le voulait Cuvier, à titre de piéces sans analogues mais en se rattachant au développement si général et si considérable des expansions tégumentaires des Poissons." Owen[2] does not commit himself definitely either way, considering them merely appendages to the "tympano-mandibular arch," but however implies a certain amount of credence in the auditory theory, by referring them to the mandibular rather than to the hyoid arcade. Lastly, Gegenbaur[3] suggests that the interoperculum was originally a part, not of the hyoid skeleton, but of the mandibular.

It is now a recognized fact that the homologues of the auditory ossicles are not to be looked for in the opercular bones, and we have remaining the theories that they are a subcutaneous system, a part of the branchiostegal system, and that the interoperculum is a part of the mandibular arcade. In *Amiurus* they seem to belong to the branchiostegal system, with the exception of the preoperculum. This is formed round a mucous canal, and is one of what may be called the mucous canal series, to which also the infraorbital ossicles belong. Functionally it is not one of the opercular bones but protects the included mucous canal. The suboperculum is properly a bone lying below the lower edge of the operculum. This is the position it holds *Esox*, also in *Salmo*, but in the latter çase it is increased in size, and projects largely from under the operculum. In both these forms also it lies on the inner side of the interoperculum. In *Amiurus*, what is usually considered the upper branchiostegal ray bears exactly the same relations. Shortly behind its attachment to the epihyal,

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[1] *Hollard*.- De la signification de l'appareil operculaire des Poissons. Ann. des Sci. Nat., 1864.

[2] *Owen*.—On the anatomy of the vertebrates. Vol. I, London, 1866.

[3] *Loc. cit.*

it lies on the inner surface of the interoperculum, and its outer portion lies below and slightly behind the operculum. Accordingly as above stated, it may be considered as equivalent to the suboperculum of other Teleosts. The operculum and interoperculum seem to have been originally a single ray, which dividing transversely, gave rise to the two bones. They are directly in apposition in *Amiurus*, the lower extremity of the operculum being of the same size as the upper (posterior) extremity of the interoperculum. With regard to the attachment of the latter to the articulare, it may be stated that it is just as firmly attached to the epihyal, which, however, it overlaps, and it is possible that it may, as Gegenbaur suggests, be the only remaining ray of the mandibular arch. However, be that as it may, it is evidently an appendage of a visceral arch, and as such, is homologous with a branchiostegal ray.

My conclusions as to the homologies of the opercular bones are as follows :—*The preoperculum is developed around a mucous canal and does not belong to the same category as the other bones. The suboperculum is a modified branchiostegal ray, and the operculum and interoperculum correspond to another ray which has become divided transversely.*

IV.—THE BRANCHIAL APPARATUS.

This consists of five arches, each arch consisting of a number of bones, the upper portion of each being bent at an acute angle, so as to lie in a plane almost parallel to that of the lower portion. In other words, the lower portions of the arches lie on the floor of the pharynx, the upper portion in its roof. In a typical arch five portions are present. Below in the middle line, extending between the arch and its successor, is an impair bone, the *copula*. Opposite the anterior end of the copula is a usually short portion—the *hypobranchial*, on the outer side of which lies the *ceratobranchial*, usually the largest of the branchial elements. Between the last-named portion and its successor, the *epibranchial*, the bend occurs, so that the extremity of the arch, formed by a usually small *pharyngo-branchial*, lies near the median line of the roof of the pharynx.

In *Amiurus* (Pl. II. Fig. 3) all the arches do not possess the typical number of bones. Only two copulæ are present, *i. e.*, those between the 1st and 2nd (cp_1), and 2nd and 3rd arches (cp_2) ; between the 3rd and 4th a cartilage ($cp_{3\text{-}4}$) is present, with the posterior ex-

tremity of which the ceratobranchial of the 5th arch articulates, and which probably represents the conjoined copulæ of the 3rd and 4th and 4th and 5th arches. Similarly osseous hypobranchials are not present in all the arches. The 1st and 2nd possess them (Hbr_1 and Hbr_2) in the form of their round bones, but in the 3rd and 4th (Hbr_3 and Hbr_4) they remain cartilaginous, and in the 5th appear to be wanting. Ceratobranchials ($Cbr_{1\text{-}5}$ are present in all the arches; they are long slightly curved bones, grooved on the under surface for the reception of the branchial vessels and nerves, and carry the majority of the gill-leaflets. The ceratohyal of the 5th arch (Cbr_5) however, departs from the normal type. It is flattened from side to side, is not grooved below, has no branchial leaflets, but bears on its upper edge an oval plate of bone possessing a large number of teeth; this is usually known as the *hypopharyngeal* (*PhI*). The epibranchials (Fig. 4, $Ebr_{1\text{-}4}$) also bear gill-leaflets to a certain extent, at least those of the 1st and 2nd arches do. These resemble slightly the ceratobranchials, but do not possess so deep a groove on the under surface, being flattened. From near the middle of the posterior border of the 3rd epibranchial a strong process (*pro*) passes backwards, inwards and upwards, serving for the attachment of muscles. The 4th epibranchial (Ebr_4) is very broad towards its inner extremities, while the 5th is wanting. The pharyngobranchials are rudimentary also. The 1st is wanting or represented only by cartilage; the 2nd (Pbr_2) acts as a copula between 2nd and 3rd epibranchials; the 3rd (Pbr_3) has a similar relation to the 3rd and 4th epibranchials; while the 4th and 5th are wanting. Thus none of the elements of the upper moiety of the 5th arch are present. Lying on the under surface, and attached to the 3rd pharyngobranchial and the inner extremities of the 3rd and 4th epibranchials, is a round osseous disc bearing numerous teeth—the *epipharyngeal* (*PhS*). To the anterior edges of the cerato- and epibranchial, and to both the anterior and posterior edges of some, are attached a number of small rays equivalent to the branchiostegal rays of the hyoid arch. These are readily removed from the arches along with the soft parts.

The only points to be noticed here in connection with the branchial arches are the relations of the epi- and hypopharyngeals. These bones are not inherent parts of the branchial arches, as is frequently supposed, but have become secondarily united to them. This is indicated by the fact that they do not belong to the same arches; the

hypopharyngeal being attached to the 5th arch, while the epipharyngeal is in relation to the 3rd and 4th arches. A stronger proof of this fact, however, is afforded by a study of the development of these bones. They are then seen to be originally quite distinct from the adjacent cartilaginous branchial arches, and to be formed by the union of the cement-plates of the teeth which they bear, and by a subsequent formation of osseous trabeculæ by osteoblasts. Their morphological significance is not hard to determine. They represent the remains of the *dermal denticles* which originally lined the mucous membrane of the buccal and branchial cavities, and which are still to be seen in those situations in certain *Selachii*[1].

V.—THE SPINAL COLUMN.

With regard to this portion of the skeleton, the greatest interest centres round the first four vertebræ and their arches, which have become very much modified in accordance with the development of a series of ossicles within the auditory apparatus and the air-bladder. These anterior vertebræ being thus intimately connected with the auditory sense-organ, will, with greater appropriateness be described in detail in the portion of this work, by Professor Wright, referring to that structure. It will be necessary, however, to denote here briefly the modifications undergone. The body of the *first vertebra* is fully formed, but its transverse processes are rudimentary, while its dorsal arch forms the *stapes* of either side, and a pair of intercrural cartilages present in front of it, are converted into the *claustra.* The body of the *second vertebra* has entirely disappeared, and become fused with the third, the fusion being indicated by two nutritive foramina at the base of the conjoined vertebræ. Its transverse process is wanting, and its dorsal arch becomes converted into the rudimentary *incus.* The body of the *third* fuses with the second and fourth; its dorsal arch is normal, and its spine is represented by the anteriorly directed process, which, arising from the broad flat plate mentioned below, extends forwards and articulates with the supraoccipital and exoccipitals; and its transverse process is transformed into the *malleus.* The *fourth vertebra* is fused with the third and fifth; its transverse process is the broad plate extending out on either side in this region, and its dorsal arch is the backwardly pro-

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[1] *O. Hertwig.* Ueber das Zahnsystem der Amphibien. Arch. fur mikr Anat. Bd. XI. supplement. 1874 See also Jenaische Zeitsch. Bd. VIII. 1874

jecting process from that plate. The *fifth* is of the normal type, all its parts being present, but its body is united anteriorly with that of the fourth. The bodies of the 2nd-5th are deeply grooved below for the reception of the aorta.

The bodies of the succeeding vertebræ as far back as the commencement of the tail fin are all similar in appearance. They are of the usual piscine amphicœlous type, but they are very much flattened at the centre of their length from above downwards, and a strong longitudinal ridge extends along the lateral surface of each, increasing the appearance of flattening. In the adult the bodies, as well as the arches, are thoroughly ossified, no notachord remaining in the centre of the bodies. In a stage incompletely ossified it may be seen that the notachord is contracted very much vertebrally, expanding rather suddenly as one approaches either extremity of the body, and resuming its full uncontracted size. The lateral ridge seems to be formed by an extension of the ossification into the adherent connective tissue along the lateral line of the column. On the upper and lower surfaces of each centrum, on either side of the middle line, is a ridge, so that viewed laterally the vertebræ do not appear extraordinarily flattened. Posteriorly in each vertebra, *i. e.*, between the attachment of successive arches, these ridges increase in height, thus forming a protection for the spinal cord or aorta between the arches

The arches are completely ossified, and are firmly anchylosed with the bodies. They unite with the anterior portions of the bodies above and below, enclosing in either case the spinal cord or the aorta. In the more anterior dorsal arches the anterior elevations of the dorsal longitudinal ridges of the centra articulate with the posterior border of the preceding arches, but posteriorly no such articulations obtain. All the dorsal arches, and the hæmal arches also in the tail region, are surmounted with long backwardly directed spinous processes ; those of the 5th-9th dorsal vertebræ inclusive being bifid for the reception of the interspinalia of the dorsal fin. The majority of the vertebræ of the trunk region have their lower arches projecting at right angles from the centrum, forming the transverse processes ; with the 6th-14th of these ribs (ossifications of intermuscular septa) articulate, the upper surfaces of their proximal portions being in contact with the under surface of the distal extremities of the transverse processes. The last two vertebræ of the

trunk bear no ribs. The hæmal arches of the last extend almost directly downwards, parallel to each other, and are connected about the middle of their length by a transverse bridge, above which runs the aorta. The first tail vertebra has the hæmal arches firmly united below, but somewhat broadened so as to separate, as it were, the trunk and tail regions. The remaining hæmal arches are exactly similar in appearance to the neural arches of their vertebræ, possessing long spinous processes, certain of which assist in supporting the interspinalia of the anal fin. There is then in *Amiurus* a gradual passage from the transverse processes of the trunk region to the hæmal arches of the tail, and thus a strong argument in opposition to the view that the hæmal arches of the tail represent the transverse processes *plus* the ribs of the trunk.

The typical features are present in all the vertebræ posteriorly until one comes to the region of the *caudal fin* (Pl. II., fig. 5). Here some modifications occur. The neural and hæmal processes of the sixth vertebra (counting from the tail) are the first that are in relation to the caudal fin rays. They do not, however, suffer any modification, and are firmly coalesced with the centrum. So with the arches of the fifth. The spinous process of the lower arch of the fourth (H_4) is somewhat expanded, and that of the third (H_3) still more so, while that of the second (H_2) forms a very broad plate, from the anterior border of which a thin plate extends to the posterior edge of the third arch. The dorsal arches ($N_{6\text{-}2}$) of these vertebræ present no modifications.

The last vertebra is, however, specially interesting. Its upper arches, instead of projecting upwards and backwards, are directly perpendicular to the axis of their centrum. The spinous process (N_1) is not coalesced with their upper extremities, but forms a distinct piece connected with them by ligament. The lower arch (H_1) is fused with a small lateral process projecting from the lower portion of the body, and expands to a broad plate in apposition with the preceding and succeeding arch. The body is somewhat modified also, wanting the lateral longitudinal ridge and the fossæ above and below it, so characteristic of the other vertebræ.

The notochord extends upwardly and backwards from the last vertebra almost at an angle of 45°. No further trace of centra are to be perceived nor of dorsal arches, but the presence of several coalesced vertebræ in this terminal filament seems to be indicated by

the presence of several hæmal arches. Of these there are in all six, the four lying immediately below the terminal filament of the notochord being separated from the other two by a distinct interval, corresponding to the longitudinal axis of the body. The lowest (*A*) (*i.e.*, the one posterior to that of the last vertebral centrum) is fused with the posterior inferior portion of the last vertebral centrum, and bears at its base a slight lateral ridge. It expands very much towards its extremity, being the broadest of all these fin-bearing arches. The next four (*B*, *C*, *D* & *E*) arise from the posterior surface of the last centrum, being fused with it. They are triangular in shape, expanding posteriorly, and diminishing in size from below upwards. The last (*F*. (*i.e.*, that immediately below the notochord) is small, and partly enclosed by the lateral bones enclosing the notochord. It seems to arise from these structures near their base.

We have thus six hæmal arches which are well developed, and specially modified for the purpose of supporting the rays of the caudal fin, the centra and upper arches corresponding to them having become aborted, or perhaps the centra are represented by the last body, several having fused to form it. Lotz[1] has investigated the structure of these vertebræ in Cyprinoids and other fishes, and in the former there appears to be an arrangement very similar to that of *Amiurus*. The specialization however does not seem to have progressed quite so far. In *Barbus* the third or second vertebra bears two dorsal arches. The spinous process of the last dorsal arch is similar to that of *Amiurus*, Lotz naming the free spinous process a 'falsche Dorn,' believing it to be either a part of the true spinous process or a free fin-bearer. I prefer the former hypothesis. The three lower arches, which have no distinct vertebræ, are fused with the last centrum, as in *Amiurus*, but the upper four are independent. It would appear from this that the last vertebral centrum really consists of three fused centra, those of the four upper hæmal arches having become aborted, the fusion of these arches with the last centrum in *Amiurus* being secondary. All these lower arches are tipped with cartilage, but there are no intervening cartilaginous pieces as in *Barbus*.

Extending back from the posterior superior angles of the last centrum on either side of the notochord filament are two bones (*NS*)

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[1] *Lotz.*—Ueber den Bau der Schwanzwirbelsäule der Salmoniden, Cyprinoiden, Percoiden und Cataphracten. Zeit. f. wiss. Zool. XIV., 1864

fused with the centrum below and protecting the terminal filament. Lotz terms these the 'grosse Deckstücke,' and believes them to be 'Bogenstücke des letzten Wirbels.' With this homology I cannot agree, for two reasons. Firstly, the spinal chord does not stand in the same relation to these bones as to the arches of the other vertebræ; it does not pass between them but lies in front (above) them in the groove which they form; posteriorly the rudiment of the nervous tract is partly enclosed, but this arises from the upward growth of the bone posteriorly, and does not correspond to a passage between two arches. Secondly, these bones are not preformed in cartilage, as their development shows, but are formed in membrane, thus belonging to a different category to the arches, which are all preformed in cartilage. These two facts appear to me to dispose of the 'Bogenstücke' theory, and the question arises as to what is their true homology. They seem to correspond both in development and relations to the dorsal longitudinal ridges of the vertebræ. They are direct continuations of these ridges which protect but do not surround the central nervous system, and are developed by an ossification of membrane.

To recapitulate, then, the homologies of the modified ventral parts of these posterior vertebræ: *The free spinous process of the second vertebra is the true spinous process of the arch of that centrum. The last centrum consists of three coalesced vertebræ, the upper arches of which have disappeared. The four succeeding centra and their upper arches have become aborted, leaving only the hæmal arches to represent them. The protecting bones on either side of the terminal filament of the chorda are continuations of the dorsal longitudinal ridges of the vertebræ, and have no relations with the arches.*

VI.—THE DORSAL FIN.

The dorsal fin adheres, to a certain extent, to the type of the impaired fins, consisting of fin-rays ossified in membrane, supported by interspinalia, which are preformed in cartilage, but the anterior rays and their interspinalia are modified for the formation of an organ of defence capable of fixation in an erected condition.

Anteriorly there is a small ossification lying in front of the large plate for the support of the defensive spine, united to it by ligament only and situated immediately below the skin. The plate with

which it articulates extends backwards as far as the posterior surface of the defensive ray, which it supports. It is of a triangular shape, broader behind than in front, and perforated by three foramina. The two anterior are small, and situated one on either side of the middle line, giving passage to the muscles which erect the small modified ray lying in front of the defensive spine. The third is large, but is divided into two parts by the extremity of the interspinal which supports the small modified ray just mentioned.

This is shaped like an inverted U or a horse-shoe, and rests astride of the extremity of the corresponding interspinal, the two limbs passing down on either side through the large posterior foramen. When erected it slides down over the anterior surface of the interspinal, and the limbs then come into apposition with the preceding expanded interspinal, so that it cannot be depressed until it is drawn upwards again to its original position. The fixation is due to this arrangement, the defensive ray being attached by a strong ligamentous band to the extremity of this modified ray. The interspinal of this horse-shoe ray is partly enclosed by the backwardly projecting and strong spinous process of the fourth vertebra, and additional strength is given by its union, by means of a thin osseous plate, to the succeeding interspinal. Its extremity is smooth and is divided by a slight transverse ridge into two parts, the posterior of which is a continuation of the osseous plate between it and the succeeding interspinal, originally formed in membrane, and, secondarily, united to the bone developed round the cartilaginous interspinal.

The succeeding ray is the defensive one. It is completely osseous, slightly curved, and terminates in a sharp point. Its base is expanded and presents three processes—two lateral, which rest on either side on the horizontal plate already described, and a ventral one which fits into a slight depression immediately behind the extremity of the interspinal of the preceding ray. Immediately above this ventral process is a perforation, which, when the ray is erected, receives the extremity of the preceding interspinal, and above this perforation is a rough surface for the attachment of the ligament by which the ray is united to the preceding one. The interspinal corresponding to this ray is situated in the cleft extremity of the spinous process of the fifth vertebra, and is united with the preceding interspinal by the thin plate already described; above it expands

and unites with the horizontal plate forming the surface on which the lateral processes of its ray rests.

The succeeding rays and their interspinalia are not modified. The latter, five in number, lie below in the cleft extremities of the spinous processes of the 6th-10th vertebræ. The rays are slightly expanded and osseous below, but towards the extremities are horny, transversely striated, and branch dichotomously.

A study of the development of these bones throws light on their homologies. The horizontal plate which supports the defensive ray, and the anterior prolongation of it, are formed in membrane (Fig. 10, *hp*). The small ossicle lying in front of it is represented at an early stage by a rod of cartilage, (*Isp.*1), lying almost in the longitudinal axis of the body. The small ∩-shaped bone is also developed in membrane, the bone on which it rests being partly formed in cartilage, (*Isp.*2) and partly (*i.e.*, the posterior part) in membrane. The defensive ray and its successors are formed in membrane, and its interspinal (*Isp.*3) and its successors are preformed in cartilage. These, then, being the facts, one must refer all those bones which are preformed in cartilage to the category of interspinals, and all those formed in membrane to that of rays. Accordingly, the anterior bone, which is united by ligament to the horizontal supporting plate, is the first interspinal, which early (even while completely cartilaginous) has lost its typical position, and the horizontal supporting plate, the anterior portion of it at any rate, is to be considered the ray corresponding to it. The interspinal enclosed within the strong fourth spinous process is then the 2nd, the small ossicle which it supports being the 2nd ray. This second interspinal has a certain amount of membrane united to it ; the lateral flanges which give a *point d'appui* for the limbs of the 2nd ray, the thin plate uniting it with the 3rd interspinal, and the portion of its extremity behind the slight groove (in reality a continuation of the thin plate), being of this nature. The third interspinal is also formed partly of cartilage and partly of membrane-bone, the portion of the horizontal plate in which the 3rd ray rests probably belonging to the membranous portion of the 3rd interspinal, which has coalesced with the modified 1st ray.

The parts of the dorsal fin may be tabulated as follows :—

1st Interspinal	Ossicle in front of horizontal plate.
1st Ray	Anterior part of horizontal plate.
2nd Interspinal	Only slightly modified.
2nd Ray	The ∩-shaped bone.
3rd Interspinal	Slightly modified ; upper portion forms the broad surface for support of 3rd ray.
3rd Ray	The defensive spine.

The succeeding interspinalia and rays are normal.

VII.—THE ANAL FIN.

The anal fin is constructed on the normal type, consisting of 21-22 rays, osseous at the base, but horny a slight distance outward. The interspinalia are completely osseous, and are not quite regular in their arrangement to the hæmal processes of the vertebræ, two interspinalia occurring at irregular intervals in the space between two processes.

VIII.—THE CAUDAL FIN.

The caudal fin is also normal. The rays here are also osseous at the base. Those in the centre are shorter than those above and below, and a few short rays run forwards a short distance above and below upon the body.

The adipose fin, containing no osseous skeleton, belongs more properly to the tegumentary system.

IX.—THE PECTORAL ARCH AND FIN.

The pectoral arch in *Amiurus* has undergone much modification, and has many points of difference from the arches of such forms as *Salmo* and *Esox*. It consists of two principal divisions, termed by Gegenbaur the *primary* and *secondary shoulder-girdles*. In the majority of the Teleosts the latter is much the larger, the former forming as it were a mere appendage to it. In *Amiurus* this is not exactly the case, for the primary girdle, or at any rate an extension of it, forms a large part of the pectoral arch. All parts of the arch are completely ossified, and considerable modifications are present in relation to the peculiar articulation of the fin ray.

The secondary shoulder-girdle consists of two pieces. The upper or *supraclavicula* (Fig. 1 *SCl*) is a T-shaped bone, of which the upper portion of the transverse limb articulates with the pterotic

and epiotic, and almost occludes the opening of the temporal fossa, while the extremity of the vertical limb articulates with the side of the basioccipital, and a process on its ventral surface near its junction with the transverse limb articulates with the stout transverse process of the fourth vertebra. The upper portion of the lower division of the secondary girdle lies in the deep groove between this process and the extremity of the lower portion of the transverse limb.

The lower piece consists of two portions coalesced, which may be denominated the *mesoclavicula* (Fig. 6 *MCl*) and *infraclavicula* (*ICl*), no trace of the constituent parts, however, persisting. Above are three processes. The anterior (*ap*) which projects directly upwards, fits into the deep groove mentioned above ; the median (*mp*) projecting backwards and upwards, lies behind the lower portion of the transverse limb of the supraclavicula, and prevents excessive downward and backward motion of the arch ; and the inferior (*ip*), which projects directly backwards, lies quite free immediately below the the skin, its outer surface being roughened by minute tooth-like tubercles. The axis of this portion is almost directly vertical, below, however, the bone curves inwards, becomes horizontal, and is united by ligament with its fellow of the opposite side. The upper surface of this portion, which is thin, is smooth. The under surface presents several points for examination. Just below the base of the inferior process mentioned above is a deep semi-circular groove (*sg*), in which the correspondingly shaped basal process of the first fin-ray runs. The ridge which bounds this on the outside is continued downwards and then inwardly on the under surface, and with a corresponding though slighter parallel ridge forms a groove. With the posterior ridge the anterior edge of the coracoid (*cor*) articulates—a broad process (*br*) extending across to the anterior ridge near its outer extremity, and thus forming in this region a canal. By the expanded outer and posterior portion of the coracoid overlapping the under surface of the coalesced meso- and infraclavicula in that region, and not further inwards, another canal is formed, which unites with the one already described, both containing parts of the same muscle. No *post-clavicula* is present.

The two pieces, *coracoid* (*cor*) and *scapula* (*sc*), of which the primary girdle is originally formed have also become quite coalesced.

The foramen (*for*), however, which usually occurs between them, is still present and indicates that while the scapular portion is very small the coracoid has reached a very great degree of development, meeting with its fellow in the middle line, and being united to it by sutural union. This coracoid has been described (by Huxley for instance) as the clavicle, but this must be a mistake, for in a well macerated skeleton, this portion separates perfectly from the portion in front, the clavicle, showing that these two are not the same. If the extension of the coracoid, towards the middle line, seen, for instance, in the *Gadidæ*, be continued still farther, the arrangement which obtains in *Amiurus* will result. The upper surface of these coalesced bones presents no point worthy of special notice, but on the ventral surface of the outer portion the following points may be noticed. First of all there is the bridge-like process (*br*) which extends over to the anterior ridge on the under surface of the *infraclavicula*, and at its base a high ridge (*r*) is to be seen which diminishes rapidly as it passes inwards, and is soon lost. Slightly exterior to this is a small rod-like process (*rp*), which articulates with the inner basalia of the fin, and from its base a fine spicule of bone (*sp*) passes transversely across to the posterior margin, its anterior portion giving an articular surface to certain of the *radialia*. This spicule forms an arch through which a muscle runs and just below its anterior point of attachment is the foramen between the scapular and coracoid portions.

From the arrangement of the articulations of the fin, and from general characters, I am inclined to refer to the scapula, the thin triangular portion, which is well marked off, and whose limit on the exterior edge would be a line drawn from the base of the rod-like process for the inner basale. The spicule-like arch belongs probably to the coracoid portion.

The fin consists of two principal rows of elements. The proximal row consists of three elements, two osseous and one cartilaginous. The posterior element (the fin being erected) is osseous, a rather slender rod tipped with cartilage at either end. Proximally it does not reach the pectoral arch, a small cartilage intervening. This is Huxley's[1] *metapterygial basale*. The next element, proceeding

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[1] *Huxley.*—Anatomy of the Vertebrates. London, 1871.

anteriorly, is similar in appearance, but stouter. Distally, like the basale, it supports the fin rays, but proximally it articulates with the upper surface of the anterior extremity of the spicule-like bridge. Between the distal ends of this, which is a *radial* and the *basale*, is a small cartilage, embraced by the fin-rays. The next element, anteriorly, is a large cartilaginous nodule, articulating with the extremity of the rod-like process of the coracoid, and supporting the fin rays. It probably represents another radial. Huxley's *mesopterygial basale* is here, as is usual, ossified with the anterior fin ray.

Concerning the majority of these structures nothing need be said but that they are on the same plan as the rays of the unpaired fins. The most anterior ray (fig. 7), however, requires special mention. It is completely ossified, terminates in a sharp point, and has the posterior edge serrated. By special arrangements it can be firmly fixed in the erect position, and can only be depressed by rotation through an angle of 90° ; it is therefore an important weapon for defence or offence. These arrangements are as follows :—From the upper surface of the base (the original mesopterygial basale) a high semi-circular ridge (*sr*) arises, and the proximal extremity terminates in two processes (*tps* and *tpi*), including a deep groove between them. When the fin is erected the semi-circular ridge runs into the semicircular groove (fig. 7 *sg*) at the base of the inferior process of the mesoclavicula, and at the same time the outer edge of the coracoid is received into the groove between the two terminal processes. Movement directly forward or directly backward is now effectually prevented, and flexion can only be accomplished by rotation, when the ridge slips out of its groove, and the outer edge of the coracoid out of its groove.

The terms applied to the different parts of the pectoral arch have varied much at different periods. The following table will illustrate this:

TERMS HERE EMPLOYED.	BAKKER.	GEOFFROY.	CUVIER.	STANNIUS.	OWEN.	HUXLEY.	GEGENBAUR.
Scapula.		Humerus.	Cubitus.	Ossa Carpi.	Radius.	Scapula.	Scapula.
Coracoid.			Radius.		Ulna.	Coracoid.	Coracoid.
Supra-clavicula	Omoplate.	Omolite.	Surscapulaire.	Omolita.	Suprascapula.	Post-temporal.	Supra-clavicles.
Meso-clavicula.	Acromion.	Omoplate.	Scapulaire.	Scapula.	Scapula.	Supra-clavicula.	
Supra-clavicula	Cœnosteon	Clavicula.	Humerus.	Clavicle.	Coracoid.	Clavicle.	Clavicle.
Post-clavicula.			(Coracoideum.)		Rib.	Post-clavicula.	Accessory piece.

X.—PELVIC ARCH AND FIN.

The pelvic arch consists of two similar pieces united in the middle line. The anterior part of each piece is very thin, and is produced into a point at the outer angle. The posterior edge is rounded, and gives articulating surfaces for the rays of the ventral fin—eight in number. Posteriorly in the middle line there is a horse-shoe shaped cartilage, the concavity of which is directed backwards, the two limbs of which give attachment to portions of the infracarinales muscles. Cristæ for the attachment of muscles traverse the thin portion, and the posterior border is edged with cartilage. According to Davidoff[1] these bones are not homologous with the pelvis of the Elasmobranchs, but correspond to the metapterygial basalia much enlarged. The pelvis of *Amiurus* corresponds very closely to the description of that of *Barbus fluviatilis* given by the same author, the horse-shoe shaped cartilage representing the stout posterior process as in that form.

The reduction of the radialia which characterises the Teleosts when compared with Elasmobranchs and Ganoids is here carried to its greatest extreme, these structures being entirely absent. The fin-rays have the usual character.

Having now described the structure of the various parts composing the skeleton of this Siluroid, it remains to point out one or two generalizations with regard to it. In the first place its relation to the Cyprinoids is close, as evidenced by the modifications of the anterior and the tail vertebræ, and also by the relations of the auditory apparatus.

Secondly, there is evidence that the Siluroids have branched off at a very early period from the primordial Teleosts. This is shown, as has been already stated, by the almost complete ossification of the skull, and also by the extent of the specialization of the various parts. The canal for the orbital muscles has almost disappeared, showing that *Amiurus* has passed through a stage in which it possessed a complete canal, a stage in which the Cyprinoids still remain. The perfectness of the arrangements for the fixation of the

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[1] *Davidoff*.—Beitrage zur vergl. Anat. d. hinteren Gliedmasse d. Fische. Morph. Jarhb. VI. 1880.

anterior ray of the pectoral fin also points to the lapse of a considerable period of time, during which small successive changes have been wrought, and the extent of the modifications of the dorsal fin for the same purpose point to the same conclusion. Other evidences of a similar nature are to be seen in the absence of any neural arches corresponding with the hæmal processes which support the rays of the caudal fin, and in the complete abortion of the radialia of the ventral fin.

All these latter points are, however, subordinate to the first in determining the relative position of *Amiurus*. Since the course of development, as is shown both by the ontological history of any form, and by the study of the various vertebrate groups, leads from a purely cartilaginous to a purely osseous skeleton, the amount of cartilage present in the skeleton of any fish is in indirect relation to the extent of its development. This character is necessarily less subject to the modification of external conditions than other parts, so that even though certain of these may undergo great specialization, yet if a considerable amount of cartilage be present in the skeleton, the form under consideration must be considered as standing comparatively low in the group. The Lophobranchiates, for instance, have undergone modifications, even more striking than those of *Amiurus*, but since the relative amount of cartilage in the skull is greater, and the parts modified may all be readily influenced by the conditions of existence, the members of this group must be placed lower among the Teleosts than *Amiurus*.

In conclusion, a few words concerning the process of ossification. From what has already been said in this paper, it will be seen that what may be termed several modes of ossification are present. We have, in the first place, the deposition of the bone in general connective tissue, forming certain of the 'Deckknochen,' and the bones around the mucous canals; we have, secondly, cement-bone, as in the premaxillæ and dentary; and we have, thirdly, perichondral bone, as in the prootic, palatine, etc. It has also been shown that all these forms of bone formation pass into one another perfectly, no dividing line marking the termination of one form and the commencement of another. Not only, however, do they thus pass into one another, but they also replace each other. This is very evident in the case of the frontal, maxillæ, vomer, parasphenoid and mucous canal bones. At one time these bones were probably formed by the union of the

cement plates, as has been shown by Hertwig,[1] but in the process of time, by a shortening of their developmental history, the bone came to be deposited directly in membrane, without any previous tooth-formation. The same thing may happen with certain perichondral bones, as, for instance, the palatine and the branchial arches. These in some Teleosts are formed from cement-bone, but in *Amiurus* are developed perichondrally, a shortening of the development again taking place.

But not only are these different varieties of bone identical in their histological features, and not only are they able to replace each other, but they also are identical in their histogenesis. In all osteoblasts are present (either transformed cartilage or connective tissue cells) and secrete the calcareous matter which is deposited in an organic non-cartilaginous substance. This is very evident in the case of the 'Deck-knochen' and mucous-canal bones. It is also the case with cement bones which are formed of osseous trabeculæ deposited in membrane by means of osteoblasts, the cement plates of the teeth themselves arising, "theils direct als Abscheidung einer zelligen Anlage (cement membran), theils durch Verknöcherung des den Zahn ungebenden Bindegewebes[2];" so that the formation of the subsequent osseous trabeculæ is merely a continuation of the original process which formed the individual cement plates. And again, with regard to the perichondral bone the same thing may be shown to obtain. With the growth of the bone secreted by the osteoblasts there is a concomitant absorption of the cartilage, the cartilage cells probably being partially transformed into osteoblasts, by whose agency new trabeculæ are formed occupying the place of the lately absorbed cartilage, there being no deposition of the calcareous matter in the cartilaginous matrix. This is what occurs in centripetal perichondral bone[3]. The processes in centrifugal perichondral bone are similar to those to be seen in the formation of cement-bone.

In the dentary portion of the mandible there is a combination of the cement process with the centrifugal perichondral process, in which union of processes is seen the close relationship between perichondral and cement-bone. For exactly the same process goes on as in the premaxillæ and the palatines. The osteoblasts which have given rise to one individual cement plate carry on their work of bone

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[1] *O. Hertwig—loc. cit.*

[2] *O. Hertwig—loc. cit.*

[3] See *Schmid-Monnard loc. cit.*

formation, producing osseous trabeculæ which replace the cartilage as it becomes absorbed, so that one might justly term the dentary a cement bone.

It has now been shown that membrane-bone, cement-bone, and perichondral bone can replace each other, that they are identical in their histological characters, and also that they are identical in their mode of formation. A comparison of the upper portions of the premaxillæ with the frontals shows that the process of bone formation is in both cases the same, and similarly a comparison of the dentary with the palatine or prootic shows that the centripetal perichondral method can start and be in relation with cement bone just as well as centrifugal perichondral bone; for in the prootic, palatine, etc., a layer of bone is first deposited outside the cartilage and by the formation of trabeculæ in connection with this, and extending out into the surrounding connective-tissue, the bone grows in thickness. There can be no good reason, then, on histogenetic grounds, for the separation of these varieties into different groups.

The Gegenbaurian distinction of bones into primary and secondary[1] is now proved to be imperfect, and consequently also Vrolik's[2] classification of bone formation into *perichonrostotisch* and *enchondrostotisch*. Walther[3] from his observations on the pike, classifies the various kinds of bone thus :—

Hautknochen	1. Cementknochen (primäre Deckknochen). 2. Bindegewebsknochen (secundäre Deckknochen). 3. Perichondralknochen (centrifugal wachsend).
Knorpelknochen	1. Perichondral (centripetal wachsend). 2. Enchondral (Bildung von Knochenkernen).

Göldi, again, in a very recent paper, objects to Walther's distinction between centrifugal and centripetal perichondral bones and classifies thus :—

I. Hautknochen	1. Cementknochen. 2. Bindegewebsknochen.
II. Perichondrale Knochen	1. Exo-perichondral (centrifugal wachsend.) 2. Endo-perichondral (centripetal wachsend),

and refers to a third group endrochondral bones, *i. e.*, those formed from a centre of ossification in the centre of the cartilage.

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[1] *Gegenbaur*—Elements of comparative anatomy.

[2] *Vrolik—loc. cit.*

[3] *Walther*—Die Entw. d. Deckknochen am Kopf-skelet des Hechtes (*Esox lucius*). Jen. Zeit. Bd. XVI., 1882.

It is a question whether from the facts of development one is entitled to lay such stress upon the presence of cartilage, and thus to separate so distinctly the perichondral from the membrane bones. I should prefer to have two classes of bone-formation (I.) that in which the calcareous matter is first deposited in the centre of the cartilage, and (II.) that in which it is not. In the first class enchondral bone would be placed and in the second the other four. But since such classification should indicate the ontogeny of the bone as well as its histogenesis, since the preformation of a bone in cartilage is of great use in determining its homologies, the second class should be subdivided. My classification would then be as follows :—

I. Bones developing from ossificatory centre in the cartilage.
    1. Endochondral bone.
II. Bones which do not develope from ossificatory centre in the cartilage.
    A. Bones preformed in cartilage :
        1. Exoperichondral (centrifugal).
        2. Endo-perichondral (centripetal).
        3. Cement bones which replace cartilage.
    B. Bones not preformed in cartilage :
        1. Membrane bones.
        2. Cement bones which do not replace cartilage.

Guelph, February 25th, 1884.

THE MYOLOGY OF *AMIURUS CATUS* (L.) GILL.

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The group of the physostomous fishes shows many structural divergences from the common type, and in the osseous and muscular systems this fact is especially noticeable. In no large group do we find the structure identical throughout the various members, but variations occur sometimes in one, sometimes in another particular, according to the natural conditions under which the animal exists. The osseous and muscular systems being so closely related, one would naturally expect to find great modifications of the one accompanied by equal modifications of the other, the extraordinary development of a muscle causing an extraordinary development of the parts to which it is attached, and, *vice versa*, the modification of a bone for any special purpose being accompanied by a suitable modification of the attached muscles.

Vetter[1] has given a detailed account of the myology of the head and arches of *Cyprinus*, *Barbus*, *Esox* and *Perca*; Cuvier[2] before him a complete account of the musculature of *Perca*; and similarly Owen[3] and Stannius.[4] In the succeeding pages I propose giving an account of the myology of *Amiurus catus*, a Siluroid, and comparing it with that of other members of the Physostomi, with the object of showing the coördinate modifications of parts and of deducing probable homologies. I may state here that I am indebted to Prof. R. Ramsay Wright for information regarding the innervation of the various muscles, he having studied this subject, so necessary in discussing homologies, in connection with the nervous system of *Amiurus*. In connection with the muscles of the head and arches, in drawing com-

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[1] *Vetter*—Untersuchungen zur vergl. Anat. der Kiemen, und Kiefer-Muskeln der Fische. Th. II., Jen. Zeit Bd. xii.

[2] *Cuvier et Valenciennes*—Hist. Nat. des Poissons, Paris, 1828.

[3] *Owen*—On the Anatomy of Vertebrates, Vol. I., London, 1866.

[4] *Stannius*—Handbuch der Zootomie, Bd. I

parison with other forms when no authority is given for statements regarding these, it may be assumed that they are drawn from Vetter's paper.

I shall divide the various muscles into the following groups, according to their present relations :—

I.—Mandibular Muscles.
II.—Muscles of the Palatine arch.
III.—Opercular Muscles.
IV.—Muscles of the Hyoid arch.
V.—Muscles of the Branchial arches.
VI.—The Trunk Musculature.
VII.—Muscles of the Pectoral arch and fin.
VIII.—Muscles of the Pelvic arch and fin.
IX.—Muscles of the Dorsal fin.
X.—Muscles of the Anal fin.
XI.—Muscles of the Caudal fin.

I.—MANDIBULAR MUSCLES.

In removing the integument from the side of the skull, one exposes a strong fascia, attached above to the frontal and supraoccipital bones, and covering the large *adductor mandibulæ.* Behind, it is attached to the descending ridge of the supraoccipital, and thence passes to the posterior border of the hyomandibular, preoperculum, and quadrate, whence it is continued on to the mandible. In front it contains behind the eye the chain of infraorbital bones. Passing below the eye, it passes forward and is attached to the antorbital process, continuing on over the nasal region, and containing the nasal and adnasal bones, to be finally inserted into the premaxillæ. On removing this fascia one exposes the

I. ADDUCTOR MANDIBULÆ, (No. 20, Cuv.; *Retractor oris*, Owen; *M. Masseter*, Ag.) (Pl. III., Fig. 1, AM.)

This is a broad thick muscle, which fills up the depression on the side of the skull. It arises from a semicircular ridge commencing anteriorly and above on the outer edge of the ectethmoid, extending thence along the frontal and supraoccipital. The muscle covers the sphenotic and pterotic, from the edges of which fibres also originate. Descending posteriorly, the line of origin passes along the posterior edge of the hyomandibular and preopercu-

lum, and thence to the quadrate. Certain fibres also take origin from the surface of the hyomandibular and from the transverse ridge on that bone. These fibres are at first distinct from the main muscle but soon unite with it. The lower fibres pass obliquely forward, and are inserted directly into the posterior edge of the process of the articulare, uniting partly with the remaining fibres. These converge towards the inner surface of the mandible, uniting to form a tendon on the inner surface of the muscle which is inserted into the longitudinal ridge on inner surface of articulare and the inner surface of the dentary, Meckel's cartilage receiving also some fibres.

Innervation.—It is supplied by the *trigeminus*. The deeper portions are supplied by a branch arising from the upper lateral strand of the trigeminus before its division into the superior and inferior maxillary branches. The superficial portions are innervated by a branch arising just behind this.

Action.—The *add. mand* raises the jaw after it has been depressed by the *geniohyoid*, and is therefore the opponent of that muscle.

In most Teleostei the *add. mand.* consists of three portions, of which the upper passes to the maxilla, the others to the mandible. In ***Esox***, an arrangement more related to that occurring in *Amiurus* obtains. The superficial portion is wanting, but the other two portions are distinct. Of these the upper, arising from the upper part of the semicircular ridge and inserted into the inner surface of the articulare and Meckel's cartilage, corresponds to the upper portions of the muscle in *Amiurus*; while the deeper one, arising from the metapterygoid and lower part of the semicircular ridge and inserted into Meckel's cartilage, a tendon uniting with that of the upper portion, corresponds with the lower portion of the muscle in *Amiurus* plus that arising from the transverse ridge and surface of the hyomandibular which here usurps the position of the metapterygoid, the slight difference in the insertion being no greater than that which obtains in ***Esox*** and *Barbus* in the deeper portions, which in these forms are clearly homologous. From the position of the muscle one may conclude that it is an angular structure, *i.e.*, belonging equally to the upper and lower moieties of the first post-oral arch, and this conclusion is confirmed by the innervation, the supplying branches leaving the trunk of the trigeminus before its division into the superior and inferior maxillary branches. Since the maxilla is a splint-bone belonging to the upper half of this arch, one would sup-

pose that originally it received a portion of the muscle, and that the arrangement now seen in *Cyprinus*, *Barbus*, and *Perca*, is the older one, that of *Esox* and *Amiurus* being the later modification.

2. ADDUCTOR TENTACULI.—(Pl. III., Fig. 1, and 2, AT)

On cutting through the insertion of the *add. mand.* and reflecting it, a muscle is exposed which is apparently characteristic of the Siluroids. It arises from the outer surface of the metapterygoid, its upper portion being covered by the *lev. arcûs palatini*. It runs forward beneath the *add. mand.*, forming the inferior boundary of the orbit and being crossed by the fifth nerve. Anteriorly it becomes tendinous, the tendon near its insertion dividing into two slips, between which the nerve supplying the tentacle passes. One of these slips is inserted into the upper, the other into the lower border of the base of the maxilla, which encloses the proximal portion of the tentacle.

Innervation.—It is supplied by a branch of the same nerve that supplies the deeper portions of the *add. mand.*

Action. It draws the tentacle backwards towards the middle line, opposing the anterior portion of the *add. arcûs palatini.*

The position and innervation of this muscle leads to the conclusion that it is a part of the *add. mand.* which has been separated off for a particular purpose. It does not, however, compare with any of the three parts of that muscle in *Barbus* or *Perca*, nor even with the fourth part, which is sometimes present, as in *Cyprinus*, since this is formed by a division of the superficial portion. Since the osseous support of the long tentacle is the maxilla, this muscle bears a certain amount of analogy to the superficial portion of the *add. mand.*, but it cannot be its homologue. The relation of the maxilla to the tentacle was probably secondary, and since the power of moving the tentacle would always have been an advantage it is probable that originally the muscle was inserted into the tentacular cartilage, its insertion into the maxilla only occurring after that bone had commenced to be a support and had enclosed the base of the tentacle. There are two theories which will account for the presence of this muscle. (1) It may be a new structure evolved for a particular purpose, or (2), it may be the representative of a muscle present in ancestral forms but which has disappeared in all the *Teleostei* hitherto examined. If the latter is the correct explanation, one

should be able to point to homologous muscles in the lower forms. Can this be done? As to the Ganoids, to which one would naturally turn, I have not been able to consult any account of their musculature, with the exception of Vetter's description of *Acipenser*, in which, apparently, no homologue is present.[1] In the Elasmobranchs[2] however, there are muscles with a certain amount of similarity. In *Chimæra* the *lev. anguli oris* consists of two portions, of which the posterior arises principally from the lower border of the orbit, is inserted into the inner surface of the posterior inferior labial cartilage, and is innervated by twigs from the *R. maxillaris inferior trigemini*. The *Plagiostomi* present a muscle even more analogous. It is absent in *Heptanchus*, in *Acanthias*, but strong in *Scyllium*, and arises from the under surface of the orbital regions of the skull. It passes forwards and is united by connective tissue to the posterior superior labial cartilage, union occurring also with the *add. mand.* It is innervated by a twig of the second branch of the *trigeminus*, which runs over the muscle into the integument of the upper lip. Vetter terms this muscle the *lev. labii superioris*.

The difference between this muscle and the *add. tent.* may possibly be explained by the presence of the membrane bones in the Teleostean skull, but nevertheless it seems that the first hypothesis is to be preferred. As I have already shown in a preceding paper, the Siluroids must have branched off very early from the original stem of the Teleosts, and have undergone much specialization. The presence of the tentacle itself is a great specialization, and since it would be of advantage to the fish that this should be capable of voluntary movement, there would be a tendency for a separation of certain fibres of the *add. mand.* for this purpose, which tendency would in the course of time result in the production of a perfectly distinct muscle. The innervation points very strongly to this theory, and the adaptation of the anterior fibres of the *add. arcûs palatini* to act as an *abductor tentaculi* also accords with it.

3. MUSCULUS INTERMANDIBULARIS, (No. 21, Cuv.) (Fig. 3, Im.)

This muscle is seen on removing the integument from the under surface of the head. It lies immediately behind the symphysis of the mandible, running transversely from one ramus to the other.

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[1] *Vetter—Loc. cit.*

[2] *Vetter*—Untersch. zur vergl. Anat der Kiemen und Kiefer-Muskeln der Fische. Th. I, Jen. Zeit. Bd. viii

Innervation.—A branch from an anastomosis of *R. maxillaris inf. trigemini* and *R. hyoideo-mandibularis facialis.*

Action.—Prevents the separation of the rami of the mandibles whether from pressure within or from the action of the *lev. arcûs palatini.*

II.—MUSCLES OF THE PALATINE ARCH.

1 LEVATOR ARCÛS PALATINI, (No. 24, Cuv.; *Lev. suspensorii*, Stan.; *Lev. tympani*, Ow.) (Figs. 1 & 2, LAP).

This is exposed on cutting through the upper and posterior portions of the insertion of the *add. mand.*, and reflecting it. The muscle may be described as consisting of two parts. The *anterior* portion is triangular and thick, and arises from the posterior border of the antorbital process and from the inferior surface and the edge of the ectethmoid and frontal. Its fibres arching over the orbit and passing below the *add. mand.*, unite to a tendon, which is inserted into the extremity of the transverse ridge of the hyomandibular. The *posterior* part is quadrangular and thin, and arises from the edge of the sphenotic. Those fibres arising from the rudimentary postorbital process are at first tendinous but soon become muscular, and, along with the more anterior ones, pass directly downwards to be inserted along the whole upper surface of the transverse ridge on the hyomandibular, a few fibres passing to the surface of the bone above the ridge.

Innervation.—It is supplied by a branch from an independent strand of the *trigeminus* which accompanies the *R. maxillaris sup.*

Action.—It raises the palatine arch. The anterior triangular portion will also pull it forwards.

This muscle is very similar in its relations to that of *Esox*, but differs slightly from that of other forms. The innervation differs also slightly, Vetter describing it in the forms he studied as being by a branch from the *R. maxillaris inferior.* Here, however, the independent strand must be equivalent to this branch, since like it it also supplies the *dilatator operculi.* The great differentiation which the trigeminus shows accounts for these slight dissimilarities.

2. ADDUCTOR ARCÛS PALATINI, (No. 22, Cuv.; *Constrictor*, Stan.; *Depressor tympani*, Ow.)

This consists of two distinct parts. The posterior portion is exposed by removing the branchial and lower part of the hyoid appara-

tus and so exposing the under surface of the skull. It is covered below by a dense fascia, in the anterior prolongation of which is the bone denominated No. 4. This *posterior portion* arises from the edges and the ascending process of the parasphenoid, and from the contiguous surface of the prootic. The fibres pass directly outwards and are inserted into the inner surface of the metapterygoid and anterior portion of the hyomandibular. The *anterior portion* may best be seen on the outer surface of the skull, after removing *add. mand.* and *lev. arc. pal.*. It arises from the parasphenoid, orbitosphenoid and upper surface of No. 4, which is developed in the fascia covering its inner surface. It passes outwards and is inserted into the inner surface of the posterior half of the palatine.

Innervation.—Both muscles are supplied by a special branch of the facial—the *R. musc. add. arcûs palatini.*

Action.—The posterior portion depresses or adducts the palatine arch after it has been raised or abducted by the *lev. arc. pal.* The anterior portion acts directly on the posterior extremity of the palatine, and indirectly through it on the tentacle. By pulling the posterior extremity of the palatine inwards it forces its anterior extremity outwards. To this is attached a portion of the dense fascia which covers the antorbital process and adjacent parts, fibres of which are also inserted into the base of the maxilla. When, therefore, the muscle acts, the fascia is rendered tense, and by the arrangement of the osseous parts acts on the maxilla, drawing the tentacle forwards. This anterior portion acts therefore as the opponent of the *add. tent.*

The muscle in *Esox* corresponds to the posterior portion in *Amiurus*, the anterior portion being apparently wanting. In *Cyprinus*, however, the origin is continued forward on the orbitosphenoid, and is more like what has been described. In neither of these forms, however, do any fibres pass to the palatine, being wholly confined to the metapterygoid and entopterygoid, and extending in *Perca* back to the hyomandibular. At first sight the anterior portion does not seem to have any relation to the posterior, since, from its lying on the outer (upper) surface of No. 4, it seems to belong rather to the outer surface of the skull than the inner. But, when the relations of that bone are considered, it is at once evident that this anterior portion is a special modification of the anterior fibres of a muscle similar to that of the Cyprinoids.

3. **Adductor Hyomandibularis**, (No. 26, Cuv. in part; *Depressor suspensiorii*, Stan.; *Depressor operculi*, Ow., in part.)

This muscle is very closely related to the *add. operculi*, lying immediately in front of it and partly overlapped by it. It arises from the lower surface of the pterotic, and passes downwards, outwards and forwards, to be inserted into the hyomandibular immediately above the opercular process.

Innervation.—Ramus opercularis facialis.

Action.—It aids the *add. arc. pal.*

The relations of this muscle correspond almost exactly with those of the corresponding muscle in *Perca*. In *Esox*, however, it is merely a part of the *add. arc. pal.*, while in the Cyprinoids it has a much greater origin and insertion than in any of the other forms.

III.—OPERCULAR MUSCLES.

1. **Levator Operculi**, (No. 25, Cuv.) (Figs. 1 & 2, LOp.)

The levator of the operculum is exposed by removing the integument from the side of the head and stripping off the posterior continuation of the fascia covering the *add. mand.* This posterior continuation is not directly continuous with the anterior portion, but takes origin from the posterior edge of hyomandibular and preoperculum, and is attached above to the edge of the pterotic and below to the upper surface of the operculum, being posteriorly continuous with the fascia covering the trunk musculature. The muscle arises from the posterior edge of the ridge on the hyomandibular, and from the edge of the pterotic. Its fibres are directed downwards and slightly backwards, and are inserted into the whole upper border of the operculum.

Innervation.—R. opercularis facialis.

Action.—It pulls the operculum upwards and slightly forwards, helping the dilatator.

2. **Dilatator Operculi**, (No. 25, Cuv., anterior part; *Lev. operculi*, ant. part, Ow.) (Fig. 2, Dil. Op.)

This muscle lies immediately below and behind the *lev. arc. pal.*, and is closely related to it. The anterior part forms a very strong tendon, which arises by muscular fibres from the under surface of the frontal and ectethmoid above the orbit and be-

low the first portion of *lev. arc. pal.* The tendon passes obliquely backwards and is inserted into the anterior and upper surfaces of the process by which the operculum articulates with the hyomandibular. The origin of the muscle is continued backwards on the ventral surfaces of the frontal and sphenotic, a few fibres arising from the latter behind the postorbital process, and posteriorly a few take origin from the surface of the hyomandibular and from the ridge on its posterior superior angle. The majority of these fibres unite with the strong tendon, only those which arise from the hyomandibular being inserted directly into the opercular knob.

Innervation.—It is innervated by a branch of the nerve which supplies the superficial portion of *add. mand.*, *i. e.*, a branch from the *trigeminus* arising behind the branch for the deep portion of *add. mand.* and *add. tent.*

Action.—Raises the operculum, and swings it outwards on its articulation with the hyomandibular.

In *Esox* this muscle is weak and does not extend forwards beyond the posterior extremity of the articulation of the hyomandibular with the pterotic. In *Perca* it reaches the sphenotic, but in none does it extend as far as in *Amiurus.* In other Teleosts the innervation is from twigs from the branch of *R. max. inf. trigemini*, which supplies the *lev. arc. pal.*, while here the innervation would indicate a closer relationship with the *add. mand.*

3. ADDUCTOR OPERCULI, (No. 26, Cuv.; *Depressor operculi*, Stan. et Ow.)

This may be seen by cutting through the insertion of the *levator operculi* and reflecting it, or better, by the dissection required for exposing the *add. arc. pal.* and *add. hyomand.* It arises from the inferior surface of the pterotic, and is inserted into the posterior edge of the upper border and the upper part of the inner surface of the operculum.

Innervation.—*Ramus opercularis facialis.*

Action.—Approximates the operculum to the side of head, and is therefore the opponent of *lev.* and *dil. operculi.*

IV.—MUSCLES OF THE HYOID ARCH.

1. Geniohyoideus, (No. 27, Cuv.) (Fig. 3, GH).

This muscle which runs along the inner side of the ramus of the mandible, may be exposed by removing the integument from the lower surface of the skull and turning back the *intermandibularis* which covers its insertion. It arises from the posterior portion of the lower (ventral) and outer surfaces of the ceratohyal, and also from the epihyal at the bases of the upper branchiostegal rays. It passes forwards as a thick muscle, inclining slightly inwards towards its fellow of the opposite side, the inner fibres being inserted into a median aponeurosis between the two, no interdigitation occurring. The greater bulk of the muscle inclines outwards, and is inserted into the posterior surface of the anterior part of the ramus of the mandible, being partly covered by the intermandibularis. Crossing the anterior portion of the muscle obliquely are two tendinous bands, (Fig. 3, ti, ti^1), to which are attached the cartilaginous supports of the tentacles of the under surface.

Innervation.—R. hyoideo-mandibularis facialis.

Action.—According as the hyoid or mandibular arches are fixed this muscle acts in different ways. If the hyoid is fixed by the *hyoclavicularis* it acts on the mandible, depressing it. This is its usual action. If, however, the mandible is fixed by the powerful *add. mand.*, it raises the hyoid arch and through it the operculum, thus aiding the *lev.* and *dil. operc.* Through the tendons which pass across it, it is the means by which the tentacles resting on these tendons move, but the range of motion thus imparted is very small.

The simplicity of this muscle contrasts somewhat with what occurs in *Esox*, and agrees more closely with the arrangement in *Barbus*. In *Cyprinus* the origin is similar, and in *Barbus* the muscles of either side do not interdigitate as they appear to do in other fishes. In *Esox* and *Cyprinus* a median enlargement of the muscle occurs. The tendinous bands are of course peculiar to the Siluroids.

2. Hyohyoideus, (Nos. 28 and 29, Cuv. ; *Lev.* and *Dep. branchiostegarum*, Ow.)

This is exposed by the dissection required for the preceding with the removal of the integument from the branchiostegal rays. It may be considered as being composed of two portions, of which the

posterior belongs essentially to the branchiostegal rays. This portion (Fig. 3, Hh[1]) arises from the inner surfaces of the operculum and interoperculum, extending from them to the dorsal border of the first branchiostegal ray Thence it passes below that ray to the dorsal border of the second, and so on to the most internal ray, becoming narrower as it nears the median line, and having its central fibres better developed than the lateral ones. From the last ray the muscle extends upwards and forwards, and is inserted into the aponeurosis which separates it from its fellow.

The anterior portion (Fig. 3, Hh[2]), arises from the upper border and surface of the ceratohyal and hypohyal, and passing inwards is inserted into the aponeurosis between it and its fellow.

Innervation.—R. hyoideo-mandibularis facialis.

Action.—Both portions act as constrictors. The posterior portion will close the aperture of the gill cavity by shutting down upon it the branchiostegal membrane. The complete closure of the "gill-slit" is necessary in order that the hyoid apparatus and its muscles may properly perform their pumping action. The anterior portion approximates the hyoid arches, and thus aids the posterior portion, drawing the whole hyoid apparatus towards the side of the skull.

The *hyohyoideus* varies somewhat in different forms. In *Esox* it passes as a continuous sheet over the branchiostegal rays, not passing from one to the other as in *Amiurus* and the Cyprinoids. In *Perca* and *Esox* the muscle passes directly across to the hyoid arch of the opposite side, and in the latter there is a separation into two bundles of which the outermost passes forward and is inserted into the ceratohyal and hypohyal, and therefore corresponds to the anterior muscle of *Amiurus*. In *Perca* neither Stannius nor Cuvier nor Owen describes an anterior portion, but Owen states[1] that "In some fishes a transverse muscle, repeating the characters of 21, Fig. 135, (*i. e.*, the intermandibularis), passes from one ceratohyal to the other." Vetter terms that portion of the muscle which runs between the branchiostegal rays the '*hyohyoideus superior*,' grouping those portions coming from the most internal ray and from the ceratohyal together as the '*hyohyoideus inferior*,' an arrangement which in *Esox* is quite proper, but will not hold with *Amiurus*.

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[1] *Owen.—Loc. cit.*

3. **Hyopectoralis**, (No. 1 Cuv.; *Retractor hyoidei*, Ow.; *Sterno-hyoid*, Stan. et Vetter.)

This muscle is exposed by removing the anterior portion of the *hyohyoideus* and the inner part of its posterior portion. It arises from the upper (dorsal) surface of the clavicle and from the strong ridge separating this muscle from the erector of the pectoral fin. It passes forwards, lying anteriorly on the upper surface of the urohyal, and being separated from its fellow by the median crest on that bone. It is inserted into the anterior portion of the urohyal below its small upper plate. (Fig. 4, Hy. P.)

Innervation.—Branch from the united first and second spinal nerves.

Action.—By its contraction it draws the anterior extremities of the hyoid arches downwards, and so enlarges the cavity of the mouth. In respiration the branchiostegal membrane closing the gill-slit, the action of this muscle will cause the flow of water into the mouth. This being then closed by the powerful *add. mand.*, the *hyo-pectoralis* and *hyohyoideus* relaxes, and the *geniohyoid* then acting, draws the hyoid arches upwards and forces the water out by the gill-slit.

I have ventured to indicate this muscle by a new name. That used by Vetter is not appropriate owing to the absence of any structure which can be termed a sternum. Owen's name also is faulty, since the action is not so much to retract the hyoids as to depress their anterior extremities. The name applied above is analogous with those of the other muscles of the hyoid arch indicating its insertion and origin.

V.—MUSCLES OF THE BRANCHIAL ARCHES.

A.—Ventral Muscles.

1. **Musculus Hyobranchialis**, (No. 35 Cuv.; *Pharyngo-hyoideus*, *Pharyngo-arcualis* and *Interac. obl. vent.* in part, Vetter).

After having exposed the hyopectoralis, it should be cut through and reflected, and the fascia covering the under surface of the branchial arches then removed. The *hyobranchialis* (Fig. 4, HBr.) will then be seen as a stout muscle lying to the side of the median line on either side on the under surface of the branchial arches. It arises from the posterior surface of the hypohyoid by a round tendon, which is continued some distance backwards on the

dorsal surface of the muscle. Opposite the second branchial arch a slip (HBr^1) separates from the main muscle and is inserted into the inner extremity of the anterior ridge of ceratobranchial iii. A second slip (HBr^2) is inserted similarly into ceratobranchial iv., the main muscle passing straight backwards to be inserted into the anterior border of the pharyngeal inferior (ceratobranchial v.) In a specimen of *Amiurus nigricans* (Les) Gill, fibres were also seen passing from the main muscle to ceratobranchials i. and ii. Certain interarcual slips run parallel to the muscle proper, and, from their relation to the slips to the ceratobranchials, may be considered as secondary parts of it. One (HBr^3) arises from the point of attachment of the slip to ceratobranchial iii., and passes back to the anterior ridge of ceratobranchial iv., its insertion being closely related with that of slip from main muscle to the same bone. A second bundle (HBr^4) continues this first one backwards, and is inserted into the inferior pharyngeal (ceratobranchial) along with the main muscle.

Action.—The hyoid being fixed it will draw the branchial apparatus forward, the interarcual slips approximating the arches to which they are attached.

As indicated by the synonyms, the muscle under consideration is probably comparable to two or more distinct muscles in other *Teleostei.* The main muscle seems to have certain analogies with the muscle in *Perca*, termed by Vetter the *pharyngo-hyoideus*, and by Owen the *branchi-depressor*, which extends from the urohyal to the inferior pharyngeals on either side. The *pharyngo-arcualis*, which is present in *Esox* and the Cyprinoids (in which the *pharyngo-hyoideus* is absent), but absent in *Perca*, also presents resemblances. It arises from the anterior border of the inferior pharyngeal, and divides into two slips, the outer of which passes to ceratobranchial iv., and is, therefore, comparable to the interarcual slip extending between the same parts in *Amiurus.* The inner portion inserts into hypobranchial iii., uniting in *Esox* with the *obliqui ventrales* of ceratobranchial iv. and hypobranchial iii. The first of these latter muscles in *Esox* and the Cyprinoids sends a slip to the ceratohyal, and that of the fourth arch besides passing to its own ceratobranchial sends also a slip to the hypobranchial iii.

I am inclined to consider the hyobranchialis of *Amiurus* as equivalent to all these parts. If one imagines the *pharyngo-hyoideus* of *Perca*, and the *pharyngo-arcualis* of *Esox* and the Cyprinoids united,

one will have a muscle passing from hyoid directly to the inferior pharyngeal, and, in addition, sending a slip from that bone to ceratobr. iv. ; and one can see in the slip of the obliquus ventralis of the fourth arch which passes forwards to the third, a homologue of the slip between ceratobrs. iii. & iv. in *Amiurus.* The hyoid and branchial arches being the hæmal arches of six of the vertebræ which enter into the skull, one may suppose that in ancestral forms there were sheets of muscle extending from one arch to the next, comparable to the myomeres of the trunk ; or rather, since these arches are so early concerned in the function of respiration, it may be imagined that each head cavity developed into muscle above and below, but aborted in its median portion. We would then have on the under surface of the branchial arches a series of muscles passing from the hyoid to first branchial arch, from that to the second, and so on. Next, the inner fibres of these myomeres united to form a muscular belly extending from the hyoid directly to the fifth arch. The outer fibres did not take part in this modification, or at least only to a partial extent, certain of them becoming detached from their anterior attachment and united to the large belly, the posterior attachment persisting. The fibres passing to ceratobrs. i. and ii. in *Amiurus nigricans,* are rudiments of these, and those to ceratobrs. iii. and iv. persisting examples. Those outer fibres which did not become modified form the interarcual slips between ceratobrs. iii. and iv., and iv. and v. In other fishes the process of specialization has gone on still farther, certain slips becoming aborted and others losing their original connections, so that the primary relations are lost.

2. Musculi Interarcuales Obliqui Ventrales, (No. 38, Cuv.)

On removing the preceding muscle, these (Fig. 4, Ob. V^1 and Ob. V^2) are exposed. They are three in number in *Amiurus,* and are small and triangular, extending from the hyobrs. i., ii. and iii., to the ceratobrs. of the same arches.

Action.—They draw the arches downwards towards the middle line and slightly forward.

These may be considered as modified representatives of the interarcual slips between the third and fourth, and fourth and fifth arches. The original course of the muscular fibres of the myomeres is represented by these latter, and since that of the fibres of the interarcuales obliqui is almost transverse, they must have been transferred

from their original position. According to this view the fibres of the first muscle originally ran from the ceratohyal to ceratobr. i., as indeed slips do in *Esox* and the Cyprinoids; those of the second from ceratobr. i. to ceratobr. ii.; and those of the third from ceratobr. ii. to ceratobr. iii. This supposition is supported by the fact that in other Teleostei there is a fourth *obliquus ventralis* and no slip between ceratobrs. iii. and iv., as in *Amiurus.*

3. MUSCULI TRANSVERSI VENTRALES, (No. 40, Cuv.; includes *Transv. pharyngei*, Vetter.)

These are two in number, exposed by the dissection required for the preceding muscles. The anterior one, (Fig. 4, TV^1), extends between the ceratobr. of either side of the fourth arch, across the lower surface of the branchial apparatus, the posterior (TV^2) holds a similar course between the inferior pharyngeals (ceratobr. v.)

Action.—They approximate the arches of opposite sides, the anterior one also drawing them slightly downwards.

The placing of the posterior muscle in a different category from the anterior, under the name of *pharyngeus transversus*, is quite unnecessary, the two being serially homologous. The origin of these muscles is indicated by the representative of the anterior one in the Cyprinoids, it being there small and merely part of one of the *obliqui ventrales.*

4. PHARYNGO-CLAVICULARIS EXTERNUS, (No. 36, Cuv.; *Branchi-retractor*, Ow.) (Fig. 4, PhE.)

This muscle and the following one may be seen by the dissection required for the hyobranchialis, *et seq.*, or still better, by dividing a specimen longitudinally exactly in the middle line. The hyopectoralis will have to be removed from its attachment to the clavicle to expose the origin. The *pharyngo-clavicularis ext.* arises from the upper surface of the clavicle behind the insertion of the hyopectoralis, and passes upwards, forwards and inwards, to be inserted into the anterior extremity of the inferior pharyngeal (ceratobr. v.)

Innervation.—Branch from the first spinal nerve.

Action.—Draws the pharyngeal backwards, downwards and slightly outwards, opposing the *transversus* and *hyobranchialis.*

5. **Pharyngo-clavicularis Internus**, (No. 37, Cuv.; *Branchi-retractor*, Ow.) (Fig. 4, Pl. In.)

A thin band-like muscle, arising from the upper surface of the clavicle near the middle line, and is inserted slightly behind the preceding.

Innervation.—Same as preceding.

Action.—Same as *pharyngo-clav. ext.*

B.—Dorsal Muscles.

6. **Musculi Levatores Branchiales**, (Nos. 30-33, Cuv.; *Branchi-levatores* and *Masto-branchialis*, Ow.; *Lev. branch. ext.* and *int.*, Vetter.)

These may be exposed from the inside by the dissection required for the *pharyngo-claviculares*, or from the outside by removing the opercular and hyomandibular apparatus and detaching the membrane extending from the upper moieties of the gill arches to the under surface of the skull. They are seven in number, three being attached to the superior pharyngeal.

(*a*) Arises from a concavity on the posterior part of the under surface of the pterotic. It is a round, stout muscle, which passes almost directly downwards, and is inserted into the posterior portion of the upper surface of the superior pharyngeal.

(*b*) Arises from the under surface of the pterotic in front of (*a*). It is broad and thin, and runs obliquely forwards to be inserted into the cartilages at the extremity of epibr. i.

(*c*) Arises from the pterotic in front of and slightly lower than (*b*). It passes down between epibrs. ii. and iii., and is inserted into the anterior portion of the upper surface of the superior pharyngeal.

(*d*) Arises from the sphenotic immediately below the articulation of the hyomandibular. It passes down between epibrs. ii. and iii., and is inserted just behind (*c*) (with whose fibres it intermingles somewhat below) into the antero-external portion of the upper surface of the superior pharyngeal.

(*e*) Is closely related to (*d*) lying on its outer surface. They arise together, and (*e*) passing downwards, is inserted into epibr. iii. at the base of its process.

(*f*) Arises in front of (*d*) and (*e*) from the sphenotic, and is inserted into the inner extremity of the anterior surface of epibr. ii.

(*g*) Arises immediately in front of the last, and is inserted into the upper surface of epibr. i, near its inner extremity.

Innervation.—(*a*) Is supplied by
(*b*) by a branch from *tr. branchialis i. vagi*; (*c*), (*d*) and (*e*) by branches from *tr. branchialis iii. vagi*; (*f*) by branch from coalesced *tr. branchialis* i. and ii., and (*g*) by a branch from the *glossopharyngeal.*

Action.—(*a*) By drawing the posterior part of the pharyngeal upwards, depresses its anterior portion; (*c*) and (*d*) act together, raising the anterior border and depressing the posterior, and at the same time the fibres of (*d*) will raise the outer border somewhat. These muscles impart a rocking motion to the superior pharyngeal, which must be very effective in grinding the food against the inferior pharyngeal; (*b*) draws the arches upwards and backwards, depressing the posterior ones; (*e*), (*f*) and (*g*) draw the arches directly upwards.

Vetter describes these muscles into two groups, '*internal*' and '*external*.' The latter in the Cyprinoids are five in number, in *Esox* three. They are inserted in the former into the pharyngo-brs. i., ii., iii. and iv., the three posterior sending a small slip to the epibr. i., ii. and iii., respectively. The fifth muscle is inserted into the posterior portion of the superior pharyngeal, and is therefore equivalent to (*a*). The external muscles are three, being inserted into the pharyngobrs. ii. and iii., and epibr. iv. It would be difficult to homologize the arrangement in *Amiurus* with that of the other described forms, but it is to be noticed that in the former the superior pharyngeal receives three muscles but only one in the latter.

7. Musculi Interarcuales Obliqui Dorsales.

These are exposed by the same dissection as the preceding, which must also be removed. They are three in number. The first arises from near the inner extremity of the posterior edge of epibr. i., and runs back above and slightly exterior to the second, to be inserted into the anterior edge of the upwardly directed process of epibr. iii. The second, large and stout, lies below the first. It arises from the posterior border of epibr. ii., near its inner extremity, and is inserted into the extremity and anterior edge of process of epibr. iii. The third arises from the inner extremity and anterior edge of the pharyngobrs., between the third and fourth arches, and, passing back, is inserted into the extremity and anterior edge of the process on epibr. iv.

Innervation.—The first is supplied by a branch from *Tr. branchialis iii. vagi,* and the second and third by a branch from *Tr. branchialis iv.* of the same nerve.

Action.—They will tend to approximate the arches, and also to tilt the posterior ones upwards.

In the *Cyprinoids* there are two sets of muscles, termed by Vetter, '*obliqui dorsales inferiores*,' and '*obl. dors. superiores.*' In *Amiurus* no such division can be made, nor is it possible to indicate homologies between the forms.

8. Musculi Transversi Dorsales, (Cuv. 34 and 39.)

Exposed by removal of the preceding muscles and by the detachment of the branchial arches from the skull. They are, like the corresponding ventral muscles, two in number. The *anterior* passes between the pharyngobrs. i., ii. and iii., of either side, the *posterior* between the ossa pharyngea superiora of opposite sides, the posterior fibres passing into the fascia forming the posterior boundary of the branchial cavity.

Action.—Approximate the arches of opposite sides.

These muscles probably correspond with the *transversi dorsales* of *Perca,* the anterior of which extends between epibr. ii., the posterior between pharyngobrs. iii. and iv. of opposite sides. In the *Cyprinoids* only a single muscle is present, which corresponds to the posterior muscle in *Amiurus.*

VI.—MUSCLES OF THE TRUNK.

These muscles, which are very numerous, one corresponding to each intervertebral region, have usually been described as forming one great muscle on each side, the great lateral muscle. This is convenient for description, the various muscles making up the great lateral mass, being serially homologous and almost identical in appearance. Each consists, in its typical form, of a muscular plate, (*myomere*), the fibres of which run parallel to the long axis of the body, and arise from and are inserted into a fibrous band (*myocomma*)[1] taking

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[1] These terms are here employed in the same manner as by Wiedersheim in his lately published "Handbuch der Vergl Anat. der Wirbelthiere." As originally used by Owen, myocomma signified the muscle, the derivation being given as κομμα--a segment. As here used its derivation will be from κομμα—a pause in a sentence

origin from the centrum and processes of each vertebra. Each *myomere*, therefore, corresponds in its position to a primitive vertebra. For the purpose of description, the lateral muscle of each side may be divided into five longitudinal parts, not in all cases perfectly separable, but still sufficiently so for the purpose.

The *first*, or *most superior portion*, is not represented anteriorly, but commencing at the posterior ray of the dorsal fin, it runs backward to the rays of the caudal fin. It is the muscle termed by Owen the *supracarinalis*, and by Cuvier *le muscle grêle supèrieur*. It consists on either side of a thin band of muscular fibres, formed by the union of slips arising by tendons from the spinous processes as far forward as that of the second vertebra behind the last interspinal of the dorsal fin. From their tendinous origins the fibres of each slip run obliquely forwards, the upper fibres being horizontal and continued over to the next myomere. This muscle belongs, as far as its action is concerned, to the dorsal fin, since its function is to depress that structure, but from its origin it is plainly comparable to the series of myomeres of the lateral musculature.

The *second portion* is the largest, and is formed of that part of the lateral muscle above the lateral line. Separated from its fellow of the opposite side, posteriorly, by the *supracarinales*, it is in contact with it anteriorly, and shows no division into myomeres. Posteriorly, however, the segmentation is distinct, especially towards the lower edge, the distinctness vanishing anteriorly more rapidly above than below. The myocommata are bent abruptly so as to form an angle pointing backwards, and, accordingly, each myomere fits into the succeeding one, a transverse section of the body cutting through several. Anteriorly this portion is inserted into the supraoccipital bone and spine, the exoccipital, epiotic and pterotic. Fibres also pass to the upper surface of the plate formed by the transverse processes of the 3rd and 4th vertebrae, and some of the more superior ones are fastened to the under surface of the plate of the dorsal fin.

The *third portion* lies immediately below the lateral line; it is not perfectly separable from the second portion, and still less so from the fourth. Its fibres anteriorly run between the transverse processes and ribs, and the myocommata from these, and posteriorly between the myocommata from the hæmal arches. In consequence of this the plane of the myomere is curved anteriorly, being horizontal in its upper portion where it is attached to the transverse processes, and vertical

below where it extends between the ribs. Toward the anterior region, where the ribs become shorter and finally vanish, this portion diminishes in breadth, the most anterior fibres being few in number and inserted into the under surface of the transverse processes of the 2nd and 3rd vertebræ.

The *fourth portion* is broad anteriorly, diminishing rapidly behind. Its fibres anteriorly extend between the lower extremities of the ribs and myocommata; posteriorly between the corresponding portions of the myocommata of the tail. The myomeres have a direction downwards and forwards, so that they are at an angle with those of the third portion. Anteriorly and below the portions of opposite sides are in contact, owing to the absence in that region of the fifth portion, and form a broad, stout muscle, which may be called the 'great ventral muscle.' The posterior fibres run directly forwards, those arising from the anterior shorter ribs downwards as well, so that there is formed between the anterior fibres of the third portion and those of the fourth a triangular space, the base of which is formed by the supraclavicle. Its floor is formed by a dense membrane, immediately below which is the swim-bladder. Anteriorly this portion is attached to the posterior border of the clavicle and to the posterior portion of the lower surface of the coracoid, so that, besides assisting portions two and three in bending the body laterally, it acts as a *retractor of the pectoral arch.* The median ventral portion is inserted by an aponeurosis into the posterior cartilaginous arch of the pelvis, forming Owen's *protractor ischii*, the more external fibres bending slightly outwards and inserting into the posterior angle of the pelvic bone.

The *fifth portion* corresponds to Owen's *infracarinalis*, and Cuvier's *muscle grêle inferieur du tronc.* It consists of two portions separated by the anal fin. The anterior moiety extends from the posterior cartilaginous arch of the pelvis to the base of the anterior ray of the anal fin. This Owen calls the *retractor ischii*, from its function of pulling the pelvis backwards after it has been drawn forwards by the fourth portion; in addition to this it has also the power, when the pelvis is fixed, of separating the rays of the anal fin. The posterior half extends between the posterior ray of the anal fin and the caudal fin, and draws the rays of the former backwards, aiding in their separation. These portions arise, similarly to the *supracarinalis*, from the extremities of the hæmal arches.

Innervation.—The fibres of each myomere are, of course, supplied by the spinal nerve corresponding to it segmentally. The *supra-carinales* are supplied by branches from the *ramus lateralis trigemini.* The muscular mass immediately in front of the dorsal fin is supplied by the dorsal branch of the fourth spinal, and the musculature anterior to that is supplied by branches from the *ram. lat. trig.*, with which the *rami dorsales ii.* and *iii.* completely unite. The *infra-carinales* are supplied by branches arising from a plexus formed by the union of the ventral branches of certain spinal nerves.

VII.—MUSCLES OF THE PECTORAL ARCH AND FIN.

Certain muscles belonging partly to this arch, but acting principally on others, have already been described, as, for instance, the *hyopectoralis*, and the *pharyngo-hyoidei externus* and *internus.* The muscles here to be considered are those which act principally on the arch, and those which move the fin. Of the former, the '*great ventral muscle*,' which acts as a retractor, has already been described.

1. TRAPEZIUS.

This muscle arises from the posterior portion of the lower surface of the pterotic, a few fibres also coming from the supraclavicle. It passes downwards, expanding as it goes, and is inserted into the base of the ascending portion of the clavicle, the more anterior fibres passing into the dense fascia which forms the posterior wall of the branchial cavity.

Innervation.—Twigs from main branch of *first spinal nerve.*

Action.—It draws the pectoral arch upwards, and also makes tense the fascia into which the anterior fibres are inserted.

In the forms described by Vetter this muscle does not apparently occur, that named *trapezius* by him being merely the superficial anterior portion of the dorsal trunk musculature, which extends between the posterior surface of the skull and the post-temporal and supra-clavicular bones The *trapezius* as here defined corresponds rather with that of the *Elasmobranchs.* Stannius mentions its occurrence *in some Teleosts.*

Owing to the modification of the anterior fin ray, whereby it can be fixed, and only lowered after a certain amount of rotation, the muscles which move it are different to a certain extent from those

of other fishes. Owen describes them in *Perca* as forming a pair, in two layers, on both the outer and inner sides of the antibrachio-carpal base: and the fibres of one layer run obliquely in a different direction from those of the other layer in both pairs of muscles. The outer pair abducts or protracts the fin, the inner pair adducts or retracts it, sweeping it back into contact with the flank: the first movement might be called 'extension,' the second, 'flexion.' The muscles in *Amiurus* can be reduced to a similar plan.

2. ABDUCTOR SUPERFICIALIS (No. 14, Cuv.; *Superficial abductor*, Ow.)

Consists of two portions, both lying in the groove on the under surface of the horizontal (inner) portion of the clavicle, and covered by the ventral musculature of the trunk. They pass over the bridge formed by the process of the coracoid, which articulates with the anterior ridge of the clavicle, and are inserted into the inferior[1] surfaces of the bases of the rays. The anterior portion (Fig. 5, AbS^1) is the smaller, and is partly concealed by the posterior. It arises from the outer portion of the anterior ridge of the clavicle, and is inserted into the inferior process of the base of the first ray. The posterior portion (AbS^2) arises from the posterior ridge and floor of the groove, and is inserted by as many tendons into the bases of the rays, except the first.

Innervation.—Supplied by a nerve arising from a branch which is composed of fibres from the external branch of *first spinal*, and from a branch from the united *second* and *third spinal.*

Action.—Abduct the fin. When the deep abductors are acting, they will also separate the rays.

3. ABDUCTOR PROFUNDUS (No. 15, Cuv.; *Deep abductor*, Ow.)

This is also divided into two portions, both of which, however, are inserted into the base of the first ray. The first (Figs. 5 and 6, AbP^1) lies below (*i.e.* dorsal to) the *abductor sup.*, and arises from the posterior surface of the anterior ridge of the clavicle and from the floor of the groove. It passes below the bridge formed by the coracoid, and is inserted with the second portion into the base of the semi-circular process of the first ray. The second portion (Figs. 5 and 6, AbP^4) arises from the upper (dorsal) surface of the coracoid

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[1] The terms '*inferior*' and '*superior*,' etc., are applied to the parts as they are when the fin is abducted, *i. e*, extended at right angles to the body.

plate, and from the under surface of the portion of the clavicle overlapping this. It passes below this overlapping portion of the clavicle, in the channel between it and the coracoid, and uniting with the first portion, is inserted with it.

Innervation.—The same as for the *abd. superf.*

Action.—This muscle abducts the first ray, and thus assists in abducting the entire fin, but at the same time it gives to the first ray the rotation which is necessary to complete its abduction and fixation. This rotation is brought about by the muscle being inserted into the upper surface of the ray.

The position of the second portion of this muscle appears somewhat anomalous, inasmuch as it is apparently in the upper surface of the arch, the *abd. superf.*, and even the other portion of the *abd. prof.*, lying in its lower surface. An examination of the structure of the arch explains the anomaly. The posterior portion of the arch which unites with its fellow by suture is not the posterior portion of the clavicle as it has been usually described, but is an enlargement of the coracoid. Now this latter lies really on the inferior surface of the arch, and therefore the upper surface of this enlargement is applied to the under surface of the clavicle, and accordingly a muscle lying upon its upper surface may yet lie on the under surface of the clavicle. Though the two portions of the deep abductor are widely separated at their origins, yet their union before insertion indicates that they originally constituted one muscle, homologous with the deep abductor of *Perca*.

4. ADDUCTOR SUPERFICIALIS.

Arises from the inner surface of the ascending portion of the clavicle and from the bridge-like spiculum of bone near its base; the deeper fibres arising from the radialia. It is inserted into the superior surfaces of the bases of all the rays, except the first, dividing into a separate tendon for each ray.

Innervation.—It is supplied by a branch from the combined *second* and *third spinal nerves*.

Action.—Adducts the fin. When the fin is abducted the rhythmical and successive action and relaxation of the superficial abductors and adductor will produce an undulatory movement of the fin.

5. ADDUCTOR PROFUNDUS, (No. 16, Cuv.)

This muscle (Fig. 5, AdP) lies below the ventral musculature. It arises from the posterior portion of the lower surface of the coracoid, extending inwards as far as the middle line. It passes below the thin bridge-like spiculum of bone on clavicle, and is inserted into the groove at the base of the semi-circular process at the base of the first ray.

Innervation.—Same nerve that supplied abductors.

Action.—It draws the ray, and with it the entire fin, towards the body. When the fin is abducted it acts obliquely on its point of insertion, and accordingly gives the rotation necessary to release the ray from its fixation.

VIII.—MUSCLES OF THE PELVIS AND PELVIC FIN.

The muscles which act on the pelvis have already been described in connection with the trunk musculature. The posterior fibres of the *great ventral muscle* and the portions of the *infracarinales* act as protractors and retractors of the pelvis.

The muscles which arise from the pelvis are those which move the fin. These are arranged in two layers on the ventral and dorsal surfaces of the pelvis, those of one side being separated from those of the other by a fibrous septum formed by a continuation backwards of the fascia which separates the two halves of the great ventral musculature. The ventral muscles act as abductors, the dorsal as adductors.

1. ABDUCTOR SUPERFICIALIS PELVIS, (Fig. 7, AdS).

Arises from the thickened outer edge of the pelvis, and posteriorly from the aponeurosis formed by the median fibres of the ventral muscle (VA) and the septum between the muscles of opposite sides. The outer fibres run almost directly backwards, the inner almost directly outwards, the former being inserted into the base of the outer ray, and the latter into that of the inner one, while the intermediate fibres pass to the intermediate rays dividing imperfectly into separate tendons.

Action.—Abducts (*i.e.*, pulls downwards) the fin, and also separates the rays.

2. ADDUCTOR PROFUNDUS PELVIS.

This is seen on removing the preceding. It arises from the surface of the pelvis and from the septum, and is inserted below the preceding into the bases of the rays.

Action.—Assists the preceding in abduction but does not separate the rays.

3. ABDUCTOR SUPERFICIALIS PELVIS.

On cutting through the insertions of the ventral trunk muscles and bending back or removing the pelvis, the dorsal muscles are exposed. The superficial muscle does not cover the deep one as in the case of its ventral equivalent, but is of a triangular shape, expanding as it passes backwards and inwards to its insertion. It arises from the thickened outer edge of the pelvis ; its outer fibres pass directly backwards, the inner ones backwards and inwards. It divides imperfectly into a number of tendons, one being inserted into the upper surface of the base of each ray.

Action.—Adducts the fin. The outer fibres also help to separate the rays.

4. ADDUCTOR PROFUNDUS PELVIS.

Lies to the inner side of the preceding. It arises from the dorsal surface of the pelvis and from the septum. Its outer fibres are stout and quickly become tendinous, passing under the superficial muscle, the inner ones being longer. It is inserted into the bases of the rays below the *add. superf.*

Action.—Aids the superficial muscle and also tends to approximate the rays.

Innervation.—The musculature of the pelvic fin is supplied by branches arising from a plexus formed by the union of the *rami vent. spinales*, x., xi., xii., xiii., and xiv. A plexus is first formed for the supply of the ventral portion of the musculature, but other branches are detached which form a similar plexus for the supply of the dorsal muscles.

The arrangement of this portion of the musculature of *Amiurus* corresponds very closely with that described by Cuvier, Stannius, &c., the only marked difference being the limitation in size of the *add. superf.*, which in *Perca* seems to cover more perfectly the *add.*

prof. Davidoff[1] in his valuable papers on the pelvis and pelvic musculature of fishes, treats the *Teleostei* very summarily, merely stating that the differences in musculature and innervation between the *Teleosts* and *Lepidosteus*, or, more especially *Amia*, are quite unimportant. In comparing *Amiurus* with his descriptions of either of the two forms mentioned, although the ground-plan is much the same yet the details are much simpler, it being impossible in *Amiurus* to distinguish, for instance, in the ventral musculature a *pars media*, or in the *abd. prof.* a *caput longum* from a *caput breve*. The names employed above for these muscles indicate their equivalency with those of the pectoral arch.

IX.—MUSCLES OF THE DORSAL FIN.

Owing to the modifications of the anterior rays of the dorsal fin in *Amiurus*, their muscles are also modified. Those of the *five posterior rays* have a typical arrangement. The *extrinsic* muscles are two in number, namely, the anterior superior fibres of the upper portion of the lateral musculature, which pass from the supraoccipital to the anterior portion of the plate which supports the defensive ray, and will have little or no action in moving the fin, and the *supracarinales* which will depress the rays.

Of the *intrinsic* muscles there are two to each ray, an *erector* and a *depressor*. The typical arrangement of these may be seen in the posterior five rays. In these each *erector* lies anterior to the depressor, and arises from the posterior border of the interspinal of the preceding ray. The *depressors* arise from the anterior border of the interspinal of the ray to which each belongs, and from the spinous process of the vertebra which supports that ray; each crosses its interspinal obliquely above so as to lie behind it. The erector is inserted into the anterior and the depressor into the posterior surface of the base of each ray.

Of the muscles of the *next anterior ray, i. e., the fourth*[2] the *depressor* is normal in its relations, arising from the anterior surface of the fourth interspinal and the extremity of the spinous process of the sixth vertebra, and, crossing over the interspinal, is inserted into the

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[1] *Davidoff*—Beitr. zur vergl. Anat. der hinteren Gliedmasse der Fische, ii. Th. Morph. Jahrb. vi., 1880.

[2] This will be the third apparent ray, the first having lost all its ray-like appearance. See paper on Osteology.

base of the posterior surface of the ray. The *erector* loses however its proper origin, arising instead from posterior edge of the horizontal plate on which the defensive (3rd) ray rests.

The *erector* of the *defensive* or *third ray* lies in the interval between the second and third interspinalia. It arises from the posterior edge of the first interspinal, the anterior edge of the second, and from the posterior portion of the expanded process of the fourth vertebra. It passes upwards and is inserted into the anterior surface of the base of the ray. The *depressor* has also its origin much increased. It arises from the sides of the third interspinal, from the anterior surface of the fourth, and from the spinous process of the fifth vertebra, and is inserted into the base of the anterior surface of the ray.

The *horse-shoe-shaped or second ray* has also an erector and depressor. The *erector* is small, and consists of a few fibres, which run obliquely backwards from their origin from the under snrface of the anterior portion of the horizontal plate, and which, passing through the foramen in this plate in company with the depressor, are inserted into the anterior surface of the extremity of one of the limbs of the ray. The *depressor* is a much stouter muscle, arising from the base and posterior surface of the anteriorly directed osseous process of the fourth vertebra, which includes the spinous process of the third. It passes upwards and backwards through the foramen in the anterior portion of the horizontal plate behind the erector, and is inserted into the extremity of the limb of the ray.

The muscles of the first ray are aborted.

Innervation.—Supplied by branches from the *ramus lateralis trigemini* with which the *R. dors. spinal.* unite.

Action.—The action of the *muscles of the posterior rays* are sufficiently expressed by their names. With regard to those of the *second ray* there is something to be said, since it is by these that the fixation of the third ray is produced, and its depression permitted. The depressor draws the horse-shoe-shaped ray downwards, so that it slips over the smooth extremity of the interspinal, and its limbs come into apposition with the flanges on the sides of the fourth spinous process which encloses its interspinal. The *third or defensive ray* is attached to the extremity of the second by ligament, so that its depression will now be impossible. In other words, it is the fixation of the second ray which causes the fixation of the third.

Depression of the defensive ray is, of course, produced by its own depressor; but it is permitted by the action of the erector of the second, which draws its ray upwards, setting it astride of its spinal process, and releasing its limbs from their apposition with the fourth spinous process, and so allowing of its depression. It is to be noticed that the erection of the third and succeeding rays is accompanied or succeeded by the contraction of the depressor of the second and similarly their depression with the action of the second erector.

The abnormal relations of these muscles can be explained by the modifications of the parts. Those of the anterior ray, which is almost unrecognizable and firmly fixed, are aborted. The interspinal of the first ray having lost its original relations and become bent upwards from its attachment to the spinous process of the third vertebra until it lies longitudinally, its muscles have lost their attachment to it, and so the erector of the second which ought to arise from its posterior surface has transferred its attachment to the more solid horizontal plate. The second depressor ought to arise from the anterior surface of the second interspinal, but the membrane bone which develops round the fourth vertebra, growing in as it were between the muscle and the interspinal, separates them, and the muscle passes farther forwards on the plate until it reaches the base of the anterior ascending process, thereby acquiring greater obliquity of action. The erectors and depressors of the third ray have in part their normal relations, but owing to the weight and ossification of the ray they have to move, have become enlarged, and extended their origin beyond the typical limits. The erector of the fourth ray has been crowded out from its original insertion by the aggression of the third depressor, and has become inserted into the horizontal plate where its action is more forcible.

X.—MUSCLES OF THE ANAL FIN.

The *infracarinales* act to a certain extent upon the rays of the anal fin. The portion named by Owen the '*retractor ischii*,' is inserted posteriorly into the base of the anterior ray, the posterior portion is inserted into the base of the posterior ray. Thus, when these act simultaneously, or even when one acts and the other remains fixed, the rays will be divaricated.

ERECTORS AND DEPRESSORS.

These are on the same plan as the muscles of the posterior rays of the dorsal fin. The *erectors* arise from the interspinals supporting the preceding ray and the hæmal process (or fascia connecting the hæmal arches) of the corresponding vertebra. The *depressors* arise from the interspinals supporting the rays to which they belong. These muscles are concealed by the lateral trunk muscles, which require to be pulled aside to expose them.

Innervation.—Supplied by branches from a longitudinal collecting stem which form a plexus into which the ventral branches of spinal nerves xix.–xxx. enter.

LATERAL MUSCLES.

These are not represented in the dorsal fin. They consist of a number of small muscles, one on each side for each ray, arising from the fascia covering the outer surface of the lateral musculature, and which, passing downwards and towards the median line, are inserted into the lateral surfaces of the bases of the rays ventral to the insertion of the erectors and depressors.

Innervation—Supplied by a superficial plexus similar to that which innervates the preceding muscles, and coming from the same spinal nerves.

Action.—By the successive contractions of the muscles of one side from before backwards, a corresponding relaxation of the opposing muscle occurring at the same time, the sinuous motion characteristic of the anal fin is produced.

XI.—MUSCLES OF THE CAUDAL FIN.

The muscles of the caudal fin are formed principally of the posterior portions of the lateral muscles of the trunk. From the intermuscular septa of the last few myomeres a fascia (Fig. 8, f) is given off, which is fastened posteriorly to the bases of the fin-rays. On contraction of the myomeres, this fascia acts on the rays and draws them either to one side or the other, as the case may be. The uppermost and lowermost portions of the myocomma forming the posterior boundary of the last myomere are prolonged into separate tendons (Fig. 8, My^1 and My^2) inserted into the abaxial[1] surface of the outer-

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[1] The terms *abaxial* and *axial* refer to the surfaces of the rays looking respectively awa from or towards the axis of the body.

most two or three rays above and below, and thus act as divaricators of the rays.

A deep layer of muscle may be seen on cutting through the attachment of the fascia and reflecting the superficial muscles. It consists of two portions separated by the vertebral column. Owing to the direction taken by the terminal filament of the notochord, the two portions are unsymmetrical, that below the column being greater than that above. The *dorsal portion* (Fig. 9, d) consists of a single muscle arising from the spinous processes of the last two or three vertebræ, and passes almost directly backwards. Three or four tendons begin near the origin of the muscle, and are inserted into the bases of the upper three or four rays.

The *ventral portion* is divisible into two parts. The upper (Fig. 9, v^1) is a triangular muscle, imperfectly separable into two parts lying dorsal to the middle line. It arises by an expanded origin from the broad surface of the fourth hæmal arch below the notochordal filament; passing upwards and backwards it crosses the dorsal portion before its insertion, and dividing into two long tendons is inserted into the axial surfaces of the two upper fin rays. It pulls them downwards towards the middle line as well as laterally, and thus acts as an opponent of the uppermost tendons of the superficial layer, and aids the intrinsic muscles. The lower part forms a broadly triangular muscular mass (Fig. 9, v^2), the base resting on the fin rays. It arises from the ' flossenträger ' and the bodies and hæmal processes of the last two or three vertebræ, the very lowest portions arising from the extremities of the hæmal processes of the fourth and fifth vertebræ (counting from behind) not reaching up to the centra. Numerous tendons run along the muscle, as a rule one for each ray, into the bases of which they are inserted. The lowermost portions are inserted into the rays imbedded in the adipose tissue, which are not functionally parts of the fin. This part of the muscle aids the superficial musculature, the lower fibres serving to approximate the rays.

The *intrinsic muscles* (Fig. 8, It), lie immediately below the integument posteriorly to the attachment of the fascia. One muscle is supplied to each ray of the fin proper, none being inserted into the fins in the adipose tissue. Each arises from the abaxial surface of a ray, and is inserted into the axial surface of the next external (*i.e.*, dorsal or ventral, as the case may be,) to it. Certain of the fibres of each

muscle do not arise from the succeeding axial ray but may be traced across it and several others to the fascia near the axial line, so that, viewed as a whole, their arrangement resembles that of a fan. The central muscles above and below lie entirely on the axial surface of the ray to which they are attached, and, since there is no median impaired ray, their fibres arise from the fascia between them and partly also from the fascia of the superficial muscle. These intrinsic muscles approximate the rays, being aided by the upper and lower portions of the deep musculature and opposing the upper and lower portions of the superficial muscles.

Innervation.—The intrinsic muscles are supplied from a plexus formed by ventral branches of spinal nerves xxxiii.–xli. The muscles above the spinal cord are supplied by branches from *R. lat. trigem.*, and from the small posterior *R. dorsales spinales.*

On comparing the myological characters of the head of a *Teleost* with those of a *Selachian*, the first point that strikes one is the absence in the former of the well-marked constrictors found superficially in the latter; in other words, the direction of the muscle fibres in the Teleosts appears to be more longitudinal than in the Selachians, and therefore the myomeres more similar to those of the trunk. It has been shown by Balfour and Gœtte that the musculature of the head develops in exactly the same manner as that of the trunk, *i.e.*, from the primitive vertebræ, and is, therefore, segmental in its origin, a myomere lying between the arches of each pair of vertebræ of which the head is composed. In *Amphioxus* there is no differentiation of the myomeres, the musculature from the tail to the head consisting of a series of similar myomeres separated by similar myocommata[1], and therefore represents more closely the original type than does the arrangement in either the Selachians or the Teleosts. Accordingly, the Teleosts would at first seem to present a more primitive type than do the Selachians, but a closer investigation shows this to be a mistake.

When one takes into consideration the presence of an osseous, and therefore more or less immovable, cranial skeleton in the Teleosts, the absence of the *constrictors* is easily understood. But even then one would suppose that in the more movable parts the constrictors

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[1] The ventral musculature of *Amphioxus* would interfere with this generalization were it not that it must be considered as belonging to a different category from the trunk musculature.

would persist to a greater or less extent. And so indeed they have done. In the Teleosts there are as representatives of the *constrictors*, the *intermandibularis*, the *add.* and *lev. arc. pal.*, *lev.* and *add. operc.*, the *transversi dorsales* and *ventrales* of the branchial arches, the *interarcuales ventrales*, etc. In these muscles the course of the fibres is parallel to a plane at right angles to the axis of the body, and they act more or less as constrictors of the parts to which they are attached. The greater mass of the constrictors of the Selachians is in relation to the branchial cavity. Where the parts about the pharynx are comparatively elastic, constrictor muscles will be, of course, of great use in diminishing that cavity, and so forcing the water out through the gills; but when, on the other hand, the parts become less movable through ossification, other arrangements for the propulsion of the water appear. Membrane bones are developed to act as valves and protections to the gills, a portion of the constrictor musculature persisting, attached to them, and the lessening of the size of the pharyngeal cavity is produced by the elevation of certain parts in the floor of the mouth, and only slightly by the approximation of the walls by constrictors. These latter, therefore, become limited to certain parts, instead of forming a more or less unbroken sheet over the branchial region.

Bearing in mind the fact that in the head there were originally a number of myomeres, as represented by the head-cavities, which have been specialized into a number of distinct muscles; and that to a very large extent the muscle fibres have lost their original direction, it is possible by means of the innervation to refer to their respective myomeres the various muscles.

The Cranial Muscles.—Leaving out of consideration the muscles of the eyeball, which belong to a myomere or myomeres in front of the mouth, the first muscle segment to be considered will be that supplied by the fifth nerve. Belonging to this there is, in the first place, the *add. mand.*, the fibres of which have, to a large extent, a longitudinal direction, and which extends between the mandibular and hyoid arches. Reasoning from analogy one would have expected to find this muscle and those belonging to the same myomere extending between the first præoral and the mandibular arches, but we find them in reality lying superficially to certain muscles supplied by the facial nerve. The development of the first præoral (or palatine) arch being in comparison with the succeeding ones so

limited, may explain the want of relation of the myomere to it, but still one would expect to find the muscles in relation to parts situated near it, *i.e.*, in front of the orbit. In the Selachians this is the case ; the origin of the *add. mand.* is in these forms entirely in front of the eye, and its action is essentially that of a constrictor. It seems that there has been first of all a gradual passage backwards of the origin of the *add. mand.*, (and also of the other *trigeminal* muscles), until in the Teleosts it has come to lie entirely behind the orbit, and that secondarily, there has been a downward growth of the muscle, so that the fibres have extended on to the *hyomandibular*, &c., the lowermost assuming a horizontal direction. The relations of the origin of the *add. mand.* in the *Cyprinoids, Perca* and *Esox*, are in support of this supposition. Vetter has pointed out that the *add. mand.* of the *Cyprinoids* is very much specialized, that of *Perca* slightly less so, and that of *Esox*, to which *Amiurus* is most comparable in this matter, more primitive than either ; and we find that in *Esox*, the most primitive form, the muscle arises in part from the cranial bones, (viz., the pterotic and sphenotic), whereas in the others the origin has passed lower down.

Why there should have been this passage backwards of the muscle to behind the orbit, it is rather difficult to say. Perhaps an explanation may be found in the fact that the muscle acts in the Teleosts more or less as a retractor of the mouth parts, justifying in this respect Owen's designation of it as the *retractor oris*. If an upward movement of the mandible were all that was required, the arrangement which obtains in the Elasmobranchs would certainly be most effective, whereas, if retraction were also required, such a backward progression would be necessary.

It may also be pointed out that since the muscle lies entirely behind the eyeball, the size of that structure will necessarily assist in determining the extent of the limitation of the origin to the hyoid arch. In *Amiurus* where the eye is so very small, the origin persists much further forward than in any of the other forms examined, in all of which the eyeball is comparatively large.

The adductor mandibulæ *of the Teleosts has been derived from a constrictor muscle ; its relations to the hyoid arch have been produced by a necessity for its action as a* retractor oris ; *and the extent of its departure from its original position is* partly *determined by the size of the eyeball.*

The nature of the *add. tentaculi* has already been considered, it being merely a separation of the deeper fibres of the *add. mand.* The *lev. arc. pal.* is plainly derived from a constrictor, but its function has been changed by the development of osseous structures, so that instead of assisting in the contraction of the pharyngeal cavity, it enlarges it by raising the hyomandibular apparatus, etc. The reason why a trigeminal muscle should act as the opponent of muscles supplied by the seventh nerve, is that the forward growth superficially of the hyoidean muscles was prevented by the presence in primitive forms of the spiracle. The *dil. operc.* is evidently a portion of the *lev. arc. pal.* adapted to the necessities of the opercular apparatus. The incongruity between its action and its innervation is even more apparent than in the *lev. arc. pal.*, but is explicable in the same way as Vetter has pointed out.

The *intermandibularis* is without doubt the representative of the most anterior ventral portions of the Selachian constrictor. It is supplied by both the fifth and the seventh nerve, and instead, therefore, of being assigned to the group of muscles supplied by the fifth nerve, as Vetter has done, it must be considered as representing the ventral portion of a constrictor layer lying between the palatine and mandibular and the mandibular and hyoidean arches. The anterior moiety of such a layer would be supplied by the fifth, and the posterior by the seventh nerve. In the Teleosts this layer has contracted in breadth very much, until it forms merely a narrow band between the extremities of the mandibular arch, but, with the gradual narrowing, there has been, so to speak, a corresponding lengthening out of the innervating branch from the *facialis* and a shortening of that from the *trigeminus*, so that even when limited to the mandibular arch it still possesses its hyoidean nerve.

Just as all the muscles of the mandibular arch (*i.e.*, those supplied by the fifth nerve), are derived from a constrictor, so are all those of the hyoid arch, (*i.e.*, those supplied by the seventh nerve.) The *add. arc. pal.* has apparently an abnormal position, extending between the skull and the palatine, metapterygoid and hyomandibular, thus coming into relation not only with the arches to which it belongs but also with the arch in front of it. The only explanation to be given for this is that the muscle has extended its insertion forwards as necessity required it. In *Amiurus*, owing to the necessity for motion of the palatine for the purpose of erecting (abducting) the tentacle sup-

porting maxilla, the muscle has extended farther forwards than in any other Teleosts hitherto described. The muscles are very mobile structures, modification being in them more frequent and more complete than in the nerves, &c.

The *add. hyomand.*, *add. operc.* and *lev. operc.*, are all very closely related, not only in position but also in innervation. They belonged originally to the same constrictor layer from which the *add. arc. pal.* developed, constituting the posterior part of it. The *lev. operc.* is a specialization of the superficial fibres of the most posterior portion—that portion from which also the *add. operc.* originated. These three muscles and the *add. arc. pal.* are comparable to the dorsal portion of the constrictor of the Elasmobranchs; the *geniohyoideus*, *hyohyoideus* and portion of the *intermand.* being comparable to its ventral portion.

The Branchial Muscles.—The muscles supplied by the *glossopharyngeal* and *vagus* are small in bulk when compared with those already discussed. In the Teleosts the muscles chiefly concerned in the respiratory act are not those belonging strictly to the branchial but those of the mandibular and hyoid arches. It is by means of these that the cavity of the mouth is increased, and thus an inflow of water produced, and it is by them also that the water is forced out below the opercular apparatus, passing in its way over the branchial filaments. Accordingly, we find the branchial muscles somewhat retrograded in bulk from the condition seen in the Elasmobranchs, and this retrogression has been accompanied by a corresponding increase in size and strength of the hyoidean and mandibular muscles.

I regret exceedingly that I cannot give details in regard to the innervation of many of the muscles, but, nevertheless, there are certain points which may be indicated. Most of the muscles of the branchial arches may also be reduced to the constrictor type, however much they may be modified. In the first place the *lev. branch.* are evidently the superior portions of the constrictor musculature, as are also the *mm. trans. dors.* and *interarc. obl. dors.* The latter have been slightly diverted from their constrictor direction, but as their name implies are still somewhat oblique. The lateral portion of the original constrictor has entirely aborted in *Amiurus*, though in certain forms, as *Esox*, muscles are found at the angles of the arches, *i.e.*, where the upper limbs join the lower. No such muscles could, however, be detected in *Amiurus*.

The ventral muscles partly represent the ventral portions of the constrictors. Certain of them retain their original transverse direction as the *transv. vent.* and the *obliqui vent.* The *hyobranchiales*, however, I feel disposed to consider as comparable to the ventral musculature of the trunk, in which case they must be considered as retaining for the greater part their original direction, the lateral portions merging into the constrictor type. A reason for this supposition is the explanation it affords for the dissimilarities between these muscles in various forms, and for the very evident relation which exists between the *obliqui vent.* and the slips from the *hyobranch.* As these points have already been treated of in connection with the description of the latter muscles, it will not be necessary to repeat them here.

The absence of any similar longitudinal muscles in the preceding arches points to the opposite view, but owing to the great changes which these have undergone, they may have disappeared by a continuation of the process by which the *intermandib.* has become so much reduced. There is a possibility that the *geniohyoid* may represent this ventral musculature, but I am rather inclined to refer it to the constrictor series.

With regard to the musculature of the head it may be concluded that, in the theoretical ancestral type of the *Teleostei*, it *consisted of two portions, a dorsal greater one, constrictor in its nature, and a ventral smaller one, the fibres of which retained their original longitudinal direction.*

The Trunk Muscles.—The *hyopectoralis* by its innervation belongs to the first, or rather to the first and second spinal segments, and is referable to the longitudinal ventral portion of those segments. This being the case its attachment to the hyoid is rather peculiar. One would expect the musculature of the first spinal segment to be attached anteriorly to the posterior surface of the last arch or myocomma of the cranium. Between the hyoid and the first spinal segment there are five arches, to the most posterior of which one would expect to find the *hyopectoralis* attached, or if it were continued further forward one would expect to find its anterior portions supplied by branches from the *trunc. branch. vagi.* This does not seem to be the case here, nor does Vetter describe any such arrangement in the forms he investigated. Probably along with the increased development of the hyoid apparatus, and the greater or

less retrogression of the branchial apparatus, there has been, *pari passu*, an extension forwards of the *hyopectoralis*. The hyoid apparatus virtually covers in the branchial arches, and the muscle losing its attachment to the fifth branchial arch has extended forwards and become attached to extremity of the hyoid, thus retaining, of course, its original innervation.

The *pharyngo-claviculares* give a certain support to this idea. The *phar.-clav. int.* appears to be composed of the most external fibres of the ventral musculature of the first or first and second spinal segments. The innervation in *Amiurus* would assign it to the first segment only, but Vetter has described its innervation as being from the first and second spinal nerves. In this case, then, we have a muscle whose fibres run in the same direction as those of the *hyopectoralis*, whose origin is the same, and whose innervation is the same, and which retains the insertion which one would assign to such a muscle on theoretical grounds, and therefore indicates that a change such as has been described above has taken place in the *hyopectoralis*.

The *pharyngo-clavicularis ext.* comes from fibres slightly external to the *internus*. Its innervation in *Amiurus* refers it to the first spinal segment. Vetter, however, states its innervation to be from the vagus. Theoretically one would certainly expect the innervation described for *Amiurus*, or even that described for the *phar.-clav. int.* by Vetter. I am inclined to believe that the innervation given by Vetter for the *externus* is a mistake, since in all its relations the muscle belongs to the spinal segments.

The musculature of the trunk is divisible into a dorsal portion, which is not however constrictor, and a ventral, of which the *hyopectoralis* is the anterior portion and the *hyobranchialis* the anterior continuation. The segmentation of the dorsal portion is very complete, and the innervation of the segments by their proper spinal nerves is throughout typical. The organs of locomotion have in certain places brought about certain departures from the general regularity. The fins, paired and unpaired, will be spoken of later. Just now attention is directed to the *supra-* and *infracarinales*. Concerning these the points to be noted are the almost complete absence of any signs of segmentation on the surface, while below it is very evident ; and, secondly, the innervation. In both cases the innervation is practically a plexus. In the *infracarinales*, branches from the ventral stems of certain spinal nerves unite to form a plexus by which the muscle is supplied, and in the *supracarinales* the *R. lat. trigem.* acts

as a collector for branches from the dorsal stems. The action of both muscles is on the fins, and the plexus is probably necessary to give the various parts of the muscle simultaneous contraction and so produce effective action on the dorsal, anal, or ventral fins.

The Pectoral Fin Muscles.—In the Teleosts the muscles of the pectoral fin have been described as consisting of two layers, an abductor and an adductor layer, each being again separated into a superficial and deep layer. At first sight the arrangement in *Amiurus* appears to depart somewhat widely from this type, but further investigation shows that the departure from it is merely apparent, the true relations of the muscles being obscured by the excessive development of the coracoid, whereby one portion of the *abductor profundus* appears to lie on a different surface of the arch from the other portion. The explanation of this has already been given in connection with the description of the muscle. With regard to the innervation of these muscles it is found that, as in higher animals, there is a well marked plexus, consisting of the first three spinal nerves. Following out the line of argument hitherto adopted, what conclusion is reached? Simply that the pectoral fin, or at any rate its musculature, is derived from three myomeres. It does not appear that this conclusion can be escaped. Dohrn, on embryological grounds, comes to the same conclusion,[1] *i.e.*, that the pectoral is formed by the accrescence of several segments. This is, of course, in direct opposition to the Gegenbaurian theory, which seems now to have received its quietus, having been founded on the structure of the fin in an exceptionally modified form, and not representing in the least the original features.

Another fact may be here pointed out. The muscles of the fin all lie on the external, inferior or posterior surface of the pectoral arch. This would tend to indicate that the arch, or a part of it, is of the nature of a rib, or is formed by the union of several rib-like structures. The manner in which certain muscles are inserted into it, and others take their origin from it, supports this theory. Perhaps, with Gegenbaur, one can after all, though in a different sense, refer the pectoral girdle to the type of a branchial or similar arch, considering the arches of the other segments of which the fin is composed either to have united with this one or to have entirely aborted.

The Pelvic Fin Muscles.—Similar remarks apply to the pelvic fin.

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[1] *Dohrn.*—Mitth aus d. Zool. Station zu Neaple, Vol. V., 1884.

A greater number of segments (5) appear, however, to enter into its composition. It may be pointed out that the direction of the fin is not exactly similar to that of the pectoral fin, which is more normal in this regard. One may suppose, however, that the absence of a true pelvic arch has something to do with this. If one imagines a partially aborted pectoral arch in the normal position, with the metapterygials, etc., directed somewhat backwards, one would have an intermediate stage between what obtains in the pectoral and pelvic fins of the Teleosts.

The Dorsal Fin Muscles.—The innervation of the *erectores* and *depressores* of the dorsal fin is similar to that for the *supracarinales*, *i.e.*, the *ram. lat. trigem.* acts as a collector for the dorsal branches of the spinal nerves, and gives off branches to the muscles. It would seem, from the relations of these muscles, and also from their innervation, that *they are serially homologous with the supracarinales.* Dohrn's views[1] on the subject of the impaired fins receives confirmation from the paired nature of the muscles, and still more from the fact that a blood-vessel passes horizontally along through the base of each ray, the ray splitting readily upwards from this channel, pointing to a coalescence of two parts, one on either side of the middle line, in the formation of the fin.

The Anal Fin Muscles.—With regard to the *erectores* and *depressores* of this fin, the remarks made on those of the fin just described apply equally well. They are really serially homologous with the *infracarinales.* The lateral muscles of the anal fin are, however, of an entirely different nature. Their innervation is from a superficial plexus similar to that supplying the *erectores* and *depressores.* The muscles lie completely outside the fascia covering the lateral muscles of the trunk, and the plexus which supplies them is peculiar in being in a similar manner superficial and formed from a plexus. The probability is that the muscles are dermal in their nature, and that the plexus is a secondary one, produced from the deeper plexus already present as the muscles gradually developed from the dermal tissue.

The Caudal Fin Muscles.—These are nearly all modified portions of the lateral musculature of the trunk. The intrinsic muscles are not, however, but must probably be referred to the class of dermal muscles. The innervation of the dorsal portions of the fin and of the anterior continuation of that dorsal portion is interesting in showing the relations of these parts to the dorsal and adipose fins.

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[1] *Dohrn.—Loc. cit.*

The various systems of muscles have now been considered, and it merely remains to give tables indicating the general relations of the various systems to each other and referring the various muscles to their proper segments. The muscles or their representatives belonging to pre-mandibular arches, I will not include in the table, as they have not been considered in the preceding pages. The first table indicates the relations of the cranial muscles, the second those of the muscles of the trunk, including under that term all the body posterior to the head.

MUSCLES OF THE HEAD.

NERVES.	DORSAL CONSTRICTOR MUSCLES.	VENTRAL LONGITUDINAL MUSCLES.
V.	Adductor mandibulæ, Add. tentaculi, Levator arcus palatini, Dilatator operculi.	Wanting.
V. & VII.	Intermandibularis.	
VII.	Adductor arcûs palatini, Add. hyomandib., Add. operculi, Levator operculi, Geniohyoideus, Hyohyoideus,	Wanting.
IX. & X.	Levatores branchiales, Musculi transversi dorsales, Interarcuales obliqui dorsales, Transversi ventrales, Obliqui ventrales.	Hyobranchialis.

MUSCLES OF THE TRUNK.

NERVES.	DORSAL PORTION	LATERAL PORTION. (Upper & Lower Division).	VENTRAL PORTION
1–3	Wanting.	Trapezius (?) Muscles of the pectoral fin. Lateral musculature, (anterior part).	Hyopectoralis. Pharyngo-claviculares. Ventral musculature, (anterior part)
3–30	Muscles of the dorsal fin. Supracarinales, (anterior portion).	Muscles of Pelvic fin. Lateral musculature, (median part)	Ventral musculature, (posterior part). Infracarinales, (anterior part). Muscles of Anal fin (except the lateral muscles.
30–End	Supracarinales, (posterior portion). Dorsal muscles of Caudal fin.	Lateral musculature, (posterior portion) Greater portion of muscles of Caudal fin.	Infracarinales, (posterior portion). Lower muscles of Caudal fin

DERMAL MUSCLES.

Lateral muscles of Anal fin, and the intrinsic muscles of Caudal.

As regards the *trapezius*, I cannot state positively whether it should come in the first or second column of the table, and with regard to how far the muscles on the dorsal region immediately behind the skull correspond to the *supracarinales* and muscles of the dorsal fin, I am equally uncertain. It is probable that the muscles corresponding to these portions have, in the anterior spinal region, completely disappeared, in consequence of the specialization of the anterior vertebræ. The fact that the erector of the second spine of the dorsal fin is attached to the base of the fourth spinous process, and this on its part is united with the posterior wall of the skull closing in above the other vertebræ, seems to favour this view.

GUELPH, June 3rd, 1884.

EXPLANATION OF PLATE II.

FIG 1.—Surface view of skull of *Amiurus catus*. *An*=adnasal, *Eeth*=ectethmoid, *EpO*=epiotic, *Fr* = frontal, *Hmd* = hyomandibular, *IOp*= interoperculum, *MEth* – mesethmoid, *Mn*=mandible, *MPt*=metapterygoid, *Mx*=maxilla, *Na*=nasal, *Op* = operculum, *Pa* = palatine, *Pmx*=premaxilla, *PrOp*=preoperculum, *PtO*=pterotic, *Qu*=quadrate, *Scl*= supraclavicle, *SO*=supraoccipital, *SpO*=sphenotic, *H*=membrane bone in fascia of add. arc. pal.

FIG. 2.—Cranium of *Amiurus catus* seen from the side and slightly from below. In addition to certain letters used in Fig. 1, there are the following :—*As*=alisphenoid, *BO*=basioccipital, *ExO* = exoccipital, *PaS*=parasphenoid, *Prf*=ectethmoid, *PrO* = proötic, *VO*= vomer, *VIII.*=foramen for glossopharyngeal, IX.=foramen for vagus.

FIG. 3.—Lower half of left branchial arches of *Amiurus nigricans*. Cbr_{1-5}= ceratobranchials 1–5, Cp_{1-4}=copulæ 1–4, Hbr_{1-4}=hypobranchials 1–4, *PhI*=pharyngeum inferius.

FIG. 4.—Upper half of right branchial arches of *Amiurus nigricans* from above. Ebr_{1-4}=epibranchials 1–4, Pbr_{2-3}=pharyngobranchials 2 and 3, *pro*=process of epibranchial 3, *PhS*=pharyngeum superius.

FIG. 5.—Posterior vertebræ and arches of *A. nigricans*. N_{1-6}=neural arches and spines, H_{1-6}=hæmal arches and spines, *A* and *B*=two lower hæmal arches without centra, *C. D, E* and *F*=four upper hæmal arches without centra, *NS*=osseous sheath of notochordal filament.

FIG. 6.—Pectoral arch of *A. catus*. *MCl*=mesoclavicular portion ; *Icl*=infraclavicular portion ; *Cor*=coracoid ; *Sc*=scapular portion ; *ap*, *mp*, *ip*=anterior, median and inferior process of mesoclavicle ; *up*=rod-like process of coracoid ; *for*=foramen between coracoid and scapula ; *sg*=semicircular groove on mesoclavicle for first ray ; *r*= ridge in coracoid ; *br*=bridge-like process on coracoid which articulates with infraclavicle ; *sp*=bridge-like spiculum.

FIG. 7.—Anterior ray of pectoral fin of *A. catus*. *Sr*=semicircular ridge, ; *tps* and *tpi*=superior and inferior terminal processes.

FIG. 8.—Transverse section through the pterotic region of a very young *A. catus*. *POt*=pterotic cartilage ; *Int*=integument ; *Hc*=horizontal semicircular canal ; *HM* = hyomandibular cartilage ; *MC*=mucous canal with a ring of bone around it.

FIG. 9,—Longitudinal section through the anterior portion of the mandible of a very young *A. catus*. *Mck*=Meckel's cartilage ; *T*=teeth ; *cp*= cement plates ; *Pc*=perichondral bone ; *MC*=mucous canal with ensheathing bone.

FIG. 10.—Transverse section through a very young *A. catus*, immediately in front of the dorsal fin. The lateral musculature has been omitted. *Int*=integment ; *hp*=anterior portion of horizontal plates of dorsal fin (1st ray) ; Isp_{1-3}=interspinalia 1, 2 and 3 ; Spp_4=spinous process of fourth vertebra ; Tp_4=expanded transverse process of fourth vertebra ; *NA5*=neural arch of fifth vertebra ; *NC*=notochord ; *N*=nervous cord ; *Ao* = aorta ; *Msc*=muscle.

FOLD OUT

EXPLANATION OF PLATE III.

Fig. 1.—Head of *Amiurus Catus*, after removal of the integument and superficial fascia. *Pmx* = premaxillæ; *Na* = nasal; *An.* = adnasal; *Eth* = Mesethmoid; *Prf* = Ectethmoid; *Fr* = Frontal; *SO* = Supraoccipital; *Pal* = Palatine; *Mx* = Maxilla; *Mn* = Mandible; *Qu* = Quadrate; *Op* = Operculum; *Brst* = Branchiostegal rays; *E* = Eye; *S. Ob* = Superior oblique; *E. R.* & *S. R* = External and Superior Recti.

AM = Adductor mand.; *AT* = Add. tentaculi; *LAP* = Lev. arcûs pal.; *LOp* = Lev. operc.

Fig. 2.—Same as preceding, but with add. mand. removed. In addition to certain letters in preceding figure the following occur: *ExPt* = No. 4; *MPt* and *EnPt* = portions of the Metapterygoid; *Pf* = Sphenotic; *PtO* = Pterotic.

AdT = Add. tentaculi; *Dil. Op* = Dilat. operculi.

Fig. 3.—Under surface of head of *A. Catus*. *GH* = Geniohyoideus; Hh^1 = upper yortion of Hyohyoideus; Hh^2 = lower portion of Hyohyoideus; *Im* = Intermandibularis; *ti* and ti^1 — tendinous bands to extremities of which tentacles are attached.

Fig. 4.—Under surface of branchial arches of *A. Catus*, the hyoid being removed. *UHy* = Urohyal; *HyH* = Hypohyal; I., II., III., IV., V. = Branchial arches.

HyP = Cut ends of the Hyopectoralis; *HBr* = main portion of Hyobranchialis; HBr^1 = slip of same to Ceratobr. iii.; HBr^2 = slip to Ceratobr, iv.; HBr^3 = slip between Ceratobrs. iii, and iv.; HBr^4 = slip between Ceratobrs. iv. and v.; TV^1 and TV^2 = anterior and posterior Transv. vent.; *PhEx* = Pharyngo-clav. externus; *PhIn* — Pharyngo-clav. internus; ObV^1 = and ObV^2 = first and second Obliqui Ventrales.

Fig. 5.—Transverse section (partly diagrammatic) through the pectoral arch, slightly ventral to the articulation of the fin. (This and the succeeding figure are in reversed position, ths clavicle should be below.) *Cl* = Clavicle; *Cor* = Coracoid: the letters point to the bridge articulating with the Clavicle; *sp* = Spiculum on Coracoid forming a bridge over Add. prof.; AbP^1 = first portion of Abd. prof.; AbP^2 = second portion of same; AbS^1 = first portion of Abd. Sup.; AbS^2 = second portion of same; *AdP* = Add. prof.

Fig. 6.—Transverse section of pectoral arch some distance nearer the median line than fig. 5. Letters same as in preceding figures.

Fig. 7.—Ventral musculature of ventral fin. VM^1 and VM^2 = median and external portions of ventral musculature of the trunk; *VA* = aponeurosis of ventral musculature of trunk; *AdS* = adductor superfic. pelvis; *C* = cartilaginous horseshoe of pelvic arch; *VF* = ventral fin.

Fig. 8.—Superficial and intrinsic muscles of the caudal fin. *Cd* = dorsal continuation of caudal fin; *I* = intrinsic muscles; My^1 and My^2 = upper and lower prolongations of myocomma; *f* = fascia; *LL* = lateral line.

Fig. 9.—Deep muscles of the caudal fin. *D* = dorsal portion; V^1 = and V^2 = upper and lower divisions of ventral portion; *ct* = connective tissue.

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